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Association of malnutrition risk evaluated by the geriatric nutritional risk index with post-stroke myocardial injury among older patients with first-ever ischemic stroke

Mu Niu[1†], Faqiang Zhang[2†], Long Wang[3], Hao Yang[2*†], Lina Zhu[4*†] and Supei Song[5*†]

Abstract

Background Post-stroke myocardial injury is a potentially preventable complication after acute ischemic stroke. Therefore, identifying modifiable variables, such as nutritional status, is crucial for reducing the risk of post-stroke myocardial injury. This study aimed to investigate the association between malnutrition risk on admission, as evaluated by the Geriatric Nutritional Risk Index (GNRI), and post-stroke myocardial injury in elderly patients with first-ever ischemic stroke.

Methods We conducted this study using the GNRI score to evaluate the nutritional status of older patients with first-ever ischemic stroke. The primary outcome of interest was post-stroke myocardial injury. Restricted cubic spline (RCS) was executed to assess the dose–effect relationship between the GNRI score and post-stroke myocardial injury. The correlation of malnutrition risk identified by GNRI score for post-stroke myocardial injury was examined using multivariate logistic regression analysis. To balance the potential confounders and verify the robustness of the results, propensity score matching (PSM) was further conducted.

Results Based on the GNRI score, 30.8% of patients were at moderate to severe risk of malnutrition. The overall incidence of post-stroke myocardial injury was 33.2%. The adjusted RCS analysis revealed a negative dose–response relationship between the GNRI score and post-stroke myocardial injury (*P* for non-linearity = 0.536). After adjusting for confounders, moderate to severe malnutrition risk, as evaluated by the GNRI score, was substantially associated with an increased risk of post-stroke myocardial injury (OR: 3.25; 95% CI: 1.93–5.48; $P < 0.001$). Following PSM adjustment, the association between the GNRI score and post-stroke myocardial injury remained significantly robust (OR: 4.28; 95% CI: 2.34–7.83; $P < 0.001$).

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Conclusion Malnutrition risk on admission is associated with higher risk of post-stroke myocardial injury among elderly patients with first-ever ischemic stroke. Early screening for malnutrition risk is crucial in the management of patients with first-ever ischemic stroke.

Keywords Geriatric nutritional risk index (GNRI), Nutritional status, Malnutrition screening tools, Post-stroke myocardial injury, First-ever ischemic stroke

Introduction

The risk of cardiac complications significantly increases following an acute stroke [1]. Post-stroke myocardial injury is a common stroke-induced cardiac complication that contributes significantly to the rise in cardiovascular diseases and mortality [2]. Therefore, identifying potential modifiable risk factors for stroke-induced myocardial injury may enhance the stratification of high-risk patients and facilitate the timely implementation of targeted preventive interventions.

Malnutrition due to starvation, disease, or aging can be defined as a state of lack of food intake or uptake with a negative nutrient balance, described by weight loss, reduced BMI, or reduced muscle mass. Being malnourished or at risk of malnutrition has been recognized not only as a key pathogenetic factor of various diseases but also as an important risk factor for poor clinical outcomes in stroke patients [3]. The assessment of nutritional status and nutrition intervention have gradually gained more attention [4]. Several nutritional screening tools, including the Nutritional Risk Screening 2002 (NRS 2002) [5, 6], Mini Nutritional Assessment tool (MNA) [7], and Subjective Global Assessment (SGA) [8], have been conducted for assessing nutritional status in clinical practice. However, these nutritional assessment approaches require the active cooperation of cognitively normal adults, careful inquiry by seasoned professionals, and acquisition of recent weight loss, rendering the assessments highly subjective and arbitrary [9]. Additionally, some acute stroke patients may suffer from confusion, decreased consciousness, or even coma, making these subjective tools unsuitable for malnutrition risk assessment. Geriatric Nutritional Risk Index (GNRI), an objective nutritional tool, has been developed for nutritional risk assessment [10]. GNRI score has exhibited relatively good predictive performances for mortality [11], cardiovascular events [12], major disability [13], and long-term survival after cancer treatment [14]. However, the relationship between GNRI score and post-stroke myocardial injury in elderly patients with acute ischemic stroke (AIS) has not been unequivocally addressed.

Therefore, we aimed to investigate and quantify the clinical association between malnutrition risk on admission, as indicated by the GNRI score, and post-stroke myocardial injury in elderly patients with first-ever ischemic stroke.

Methods

The study was approved by the Medical Ethics Committee of The Affiliated Hospital of Xuzhou Medical University (reference No. XYFY2022-YL117-01). Given the retrospective nature of this study, the requirement for informed consent from participants was waived. The study adhered to the current Declaration of Helsinki principles and applicable STROBE guidelines. Before performing statistical analyses, all identifiable data were thoroughly anonymized.

Study populations

We identified hospitalizations of Chinese older patients diagnosed with acute ischemic stroke (AIS) from January 2021 to December 2021, at the Affiliated Hospital of Xuzhou Medical University, a 4150-bed university-affiliated tertiary center. The inclusion criteria for the study were as follows: To be eligible for this study, participants had to meet all the following inclusion criteria: (1) aged 65 years or older; (2) patients received a primary diagnosis of AIS within 24 h of symptoms onset; (3) AIS was diagnosed according to the World Health Organization definition, and confirmed radiologically by head computerized tomography (CT) or brain magnetic resonance imaging (MRI). The exclusion criteria included (1) prior history of stroke or transient ischemic attack (TIA) of any type, (2) a medical history of hepatic or hematological diseases affecting serum albumin level, (3) previous diagnosis of cancer, and (4) missing data on baseline clinical variables or outcomes. We also excluded patients with prior cardiovascular diseases or surgeries, including myocardial infarction, coronary artery disease, congestive heart failure, valvular heart disease, atrial fibrillation, percutaneous coronary intervention, coronary artery bypass graft surgery, valve replacement/repair, and other severe cardiovascular diseases.

Data collection and definitions

Demographic and clinical data were obtained from the patients electronic medical records by trained investigators who were blinded to the study protocol. Baseline characteristics data included age, sex, height, weight,

body mass index (BMI), systolic blood pressure (SBP), diastolic blood pressure (DBP), current smoking, alcohol consumption, hypertension, diabetes mellitus, chronic obstructive pulmonary disease (COPD), peripheral vascular disease, and renal dysfunction. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2) and categorized according to guidelines recommendations for Chinese adults: underweight (BMI < 18.5 kg/m^2), normal weight (18.5 ≤ BMI ≤ 23.9 kg/m^2), overweight (24.0 ≤ BMI ≤ 27.9 kg/m^2), and obesity (BMI ≥ 28.0 kg/m^2) [15]. Stroke severity on admission, presence of dysphagia, stroke subtype, and medications administered during hospitalization (e.g., intravenous thrombolysis or endovascular treatment) were also recorded. Admission stroke severity was evaluated by a trained neurological clinician using National Institutes of Health Stroke Scale (NIHSS) and Glasgow Coma Scale (GCS). Stroke subtyping was determined with the Trial of Org 10,172 in Acute Stroke Treatment (TOAST) classification system and Oxfordshire Community Stroke Project (OCSP) criteria. The TOAST system classified ischemic stroke into 5 categories: cardioembolism, large artery atherosclerosis, small vessel occlusion, other determined etiologies, and stroke of undetermined etiology. Such patients classified as cardioembolism were excluded according to the study design. Based on the OCSP criteria, stroke subtype on admission was categorized into lacunar infarct, partial anterior circulation infarct, total anterior circulation infarct, or posterior circulation infarct. Blood samples were obtained and processed within 24 h of hospital admission. Hemoglobin, albumin, blood glucose, triglycerides, total cholesterol, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol were analyzed.

High-sensitivity cardiac troponin T or I was measured 2–3 days post-stroke with fifth- generation assay. Additionally, symptoms of myocardial ischemia (chest pain or radiation to the jaw, neck, arms, or back, and shortness of breath or dyspnea) or ischemic changes on electrocardiogram were also abstracted from the medical records.

Nutritional screening tool

The GNRI score was utilized to evaluate the nutritional risk of the participants in our study (Supplementary Table 1), which had been previously validated for nutritional risk assessment across different medical populations. The GNRI score is calculated using the following formula: 1.489 × serum albumin (g/l) + 41.7 × (current body weight [kg]/ideal body weight [kg]). Based on the Lorentz equations, the ideal body weight is specified as follows: height (cm) − 100 − ([height (cm) − 150]/2.5) for women; height (cm) − 100 − ([height (cm) − 150]/4) for men. GNRI score of > 98 indicates normal; 92 to 98, 82 to < 92, and < 82 indicates mild, moderate, and severe nutritional risk, respectively [10]. Due to the small sample size in the severe nutritional risk category, moderate and severe nutritional risks were combined into a single category of moderate-severe nutritional risk.

Clinical outcome

The primary outcome of interest was post-stroke myocardial injury in patients hospitalized with AIS. Post-stroke myocardial injury was characterized by cardiac troponin (cTn) levels above either generation-specific or assay-specific 99th percentile upper reference limit during hospital stay, which were apparently attributable to ischemic origin (with or without signs or symptoms) [16].

Statistical analysis

Patient characteristics were summarized as numbers (percentages) for categorical variables and as means ± standard deviations (SD) or median (interquartile range, IQR) for continuous variables. The dose–effect relationship between the GNRI score and post-stroke myocardial injury was visually assessed using restricted cubic spline (RCS) Results from RCS indicated that the reference point for the GNRI score was set at 92 for predicting post-stroke myocardial injury. Consequently, the patients were stratified into two groups: Low GNRI (< 92) and High GNRI (≥ 92). We performed extended logistic regression models to calculate the odds ratio (OR) and explore the potential effects of nutritional risk on the risk of post-stroke myocardial injury. To minimize the imbalance in baseline characteristics between patients with low and high GNRI scores, propensity score matching (PSM) was performed using 1:1 greedy nearest-neighbor matching strategy with a caliper width of 0.2. A standardized mean difference (SMD) below 0.1 indicated an acceptable deviation in variables between groups. Additionally, subgroup analyses were applied to assess the effect of nutritional risk on post-stroke myocardial injury according to sex, hypertension, stroke severity (NIHSS), blood glucose, and TOAST classification, as described in previous studies [17–19]. A two-sided P value < 0.05 was deemed statistically significant for all tests. All statistical analyses were conducted using SPSS software (version 26.0, IBM Corporation) and R Statistical Language (version 4.0.5, The R Foundation).

Results

Clinical characteristics

Between January 2021 and December 2021, a total of 643 elderly Chinese patients were admitted to the hospital with AIS. After employing exclusion criteria, 377 elderly patients with first-ever ischemic stroke and no prior history of cardiovascular comorbidities

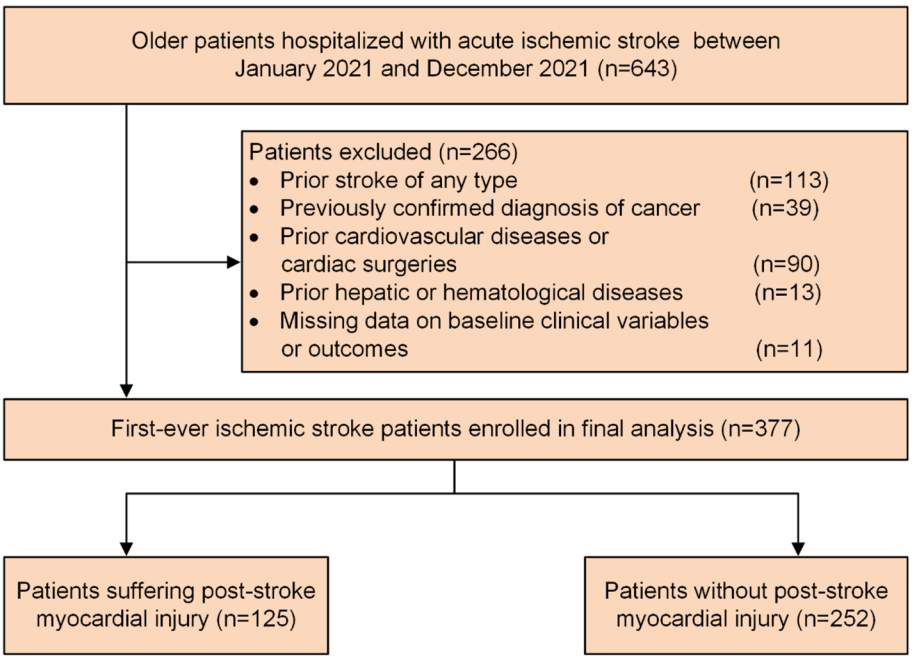

Fig. 1 Flow chart

were ultimately included (Fig. 1), with a median age of 69.0 years (IQR: 67.0, 77.0), of whom 210 (55.7%) were male. Of these admissions, the median scores of NIHSS and GCS were 4.0 (IQR: 2.0, 7.0) and 13.0 (11.0, 15.0), respectively. Within this cohort of 377 participants, 125 (33.2%) patients sustained post-stroke myocardial injury (Table 1). The incidence of post-stroke myocardial injury was consistent with previously reported rates of 30%–60% in patients with AIS [20, 21].

Results from the adjusted RCS indicated that the reference point of the GNRI score for predicting post-stroke myocardial injury was set at 92 (Fig. 2). The patients were subsequently stratified into two groups: low GNRI (< 92, $n=116$, 30.8%) and high GNRI (≥ 92, $n=261$, 69.2%). Notably, low GNRI (< 92) indicated moderate to severe risk of malnutrition. Patients in the low GNRI group exhibited greater stroke severity (NIHSS, $P<0.001$; GCS score, $P=0.002$), and lower albumin levels ($P=0.015$), than did those in the high GNRI group. Furthermore, the incidence of post-stroke myocardial injury was significantly higher in the low GNRI group compared to the high GNRI group (49.1% vs. 26.1%, $P<0.001$) (Table 2).

Prevalence and clinical association of malnutrition risk

Based on the quantitative grading of the GNRI score, 203 patients (53.8%) were identified as being at risk of malnutrition, including mild or moderate to severe risk. Among these, 116 (30.8%) patients suffered from moderate to severe malnutrition risk (Supplementary Table 2). Patients suffering post-stroke myocardial injury had higher incidence of malnutrition risk (71.2% vs. 45.2%, $P=0.002$) and moderate to severe malnutrition risk (45.6% vs. 23.4%, $P=0.005$), than did those without post-stroke myocardial injury (Supplementary Table 2, Fig. 3A). The prevalence of malnutrition risk across different BMI classification subgroups was further illustrated in Fig. 3B. Moderate to severe malnutrition risk was most prevalent among underweight patients (80.2%). Moderate to severe malnutrition risk was also significant in overweight (29.1%) and obese (27.4%) patients.

Impact of nutritional risk on post-stroke myocardial injury

The adjusted RCS analysis revealed a negative dose–response relationship between the GNRI score and post-stroke myocardial injury (P for non-linearity = 0.536) (Fig. 2). Then, we performed univariate and multivariate logistic analyses to explore the relationship between the GNRI score (both as a continuous and as a categorical variable) and post-stroke myocardial injury. In univariate analysis, GNRI score as a continuous variable was negatively correlated with post-stroke myocardial injury [odds ratio (OR): 0.92; 95% confidence interval (CI): 0.89–0.96; $P<0.001$]. After adjusting for sex, hypertension, diabetes mellitus, NIHSS score on admission, albumin, blood glucose, triglycerides, and HDL-C, the adjusted OR for GNRI score was 0.91 (95% CI: 0.88–0.95; $P=0.023$) (Supplementary Table 3). Further, we evaluated the predictive value of GNRI score as categorical variable (low GNRI

Table 1 Baseline characteristics of the patients by incident post-stroke myocardial injury

Variables	Overall (*n* = 377)	Patients suffering post-stroke myocardial injury (*n* = 125)	Patients without post-stroke myocardial injury (*n* = 252)	*P* value
Demographics				
Age, y	69.0 (67.0, 77.0)	70.0 (68.0, 78.0)	69.5 (67.0, 76.0)	0.532
Male (%)	210 (55.7)	82 (65.6)	128 (50.8)	0.006
Height, cm	165.0 (160.0, 171.0)	168.0 (160.0, 172.0)	165.0 (160.0, 170.0)	0.211
Weight, kg	67.5 (60.0, 75.0)	65.0 (60.0, 75.0)	68.0 (60.0, 75.0)	0.734
BMI, kg/m^2	24.5 (22.4, 26.0)	24.4 (22.5, 25.7)	24.8 (22.4, 26.6)	0.193
SBP, mmHg	135.0 (124.0, 147.0)	138.0 (125.0, 151.0)	134.0 (123.5, 145.3)	0.153
DBP, mmHg	80.0 (73.0, 87.0)	80.0 (75.0, 89.0)	80.0 (72.0, 87.0)	0.600
Current smoking (%)	123 (32.6)	40 (32.0)	83 (32.9)	0.855
Alcohol (%)	107 (28.4)	39 (31.2)	68 (27.0)	0.393
Previous medical history				
Hypertension (%)	197 (52.3)	80 (64.0)	117 (46.4)	0.001
Diabetes mellitus (%)	104 (27.6)	55 (44.0)	49 (19.4)	< 0.001
COPD (%)	18 (4.8)	4 (3.2)	14 (5.6)	0.313
Peripheral vascular disease	77 (20.4)	28 (22.4)	49 (19.4)	0.503
Renal dysfunction[a]	8 (2.1)	2 (1.6)	6 (2.4)	0.620
Clinical characteristics				
Admission NIHSS score, unit	4.0 (2.0, 7.0)	6.0 (3.0, 8.0)	3.0 (2.0, 6.0)	< 0.001
Admission GCS score, unit	13.0 (11.0, 15.0)	12.0 (9.0, 13.0)	13.0 (12.0, 15.0)	0.009
Dysphagia (%)	60 (15.9)	20 (16.0)	40 (15.9)	0.975
TOAST stroke subtype (%)[b]				
Large-artery atherosclerosis	162 (43.0)	51 (40.8)	111 (44.0)	0.731
Small-vessel occlusion	23 (6.1)	6 (4.8)	17 (6.8)	
Stroke of other determined etiologies	48 (12.7)	18 (14.4)	30 (11.9)	
Stroke of undetermined etiology	144 (38.2)	50 (40.0)	94 (37.3)	
OCSP stroke subtype (%)				
Lacunar infarct	23 (6.1)	6 (4.8)	17 (6.8)	0.878
Partial anterior circulation infarct	156 (41.4)	54 (43.2)	102 (40.5)	
Total anterior circulation infarct	103 (27.3)	34 (27.2)	69 (27.4)	
Posterior circulation infarct	95 (25.2)	31 (24.8)	64 (25.4)	
Medications				
Intravenous thrombolysis (%)	31 (8.2)	13 (10.4)	18 (7.1)	0.278
Endovascular treatment (%)	17 (4.5)	6 (4.8)	11 (4.4)	0.848
Laboratory findings				
Hemoglobin, g/L	132.0 (121.0, 146.0)	131.0 (120.0, 147.0)	133.0 (121.8, 146.0)	0.465
Albumin, g/L	40.5 (37.9, 42.9)	39.9 (37.1, 42.0)	40.9 (38.2, 43.0)	0.008
Blood glucose, mmol/L	5.3 (4.8, 6.7)	5.8 (4.9, 7.5)	5.1 (4.7, 6.4)	< 0.001
Triglycerides, mmol/L	1.3 (0.9, 1.8)	1.4 (1.0, 2.0)	1.2 (0.8, 1.9)	0.083
Total cholesterol, mmol/L	4.4 (3.8, 5.1)	4.3 (3.8, 5.2)	4.5 (3.8, 5.1)	0.246
HDL-C, mmol/L	1.1 (0.9, 1.4)	0.9 (0.8, 1.2)	1.2 (1.0, 1.4)	< 0.001
LDL-C, mmol/L	2.7 (2.2, 3.4)	3.1 (2.3, 3.4)	2.7 (2.2, 3.3)	0.077

Patient characteristics are expressed as n (%), mean ± standard deviation, or median (interquartile range)

Abbreviations: *BMI* Body mass index, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure, *COPD* Chronic obstructive pulmonary disease, *NIHSS* National Institutes of Health Stroke Scale, *GCS* Glasgow Coma Scale, *TOAST* Trial of Org 10,172 in Acute Stroke Treatment, *OCSP* Oxfordshire Community Stroke Project, *HDL-C* High-density lipoprotein cholesterol, *LDL-C* Low-density lipoprotein cholesterol

[a] Creatinine > 177 μmol/L

[b] Under TOAST, the subgroup of cardioembolism is excluded

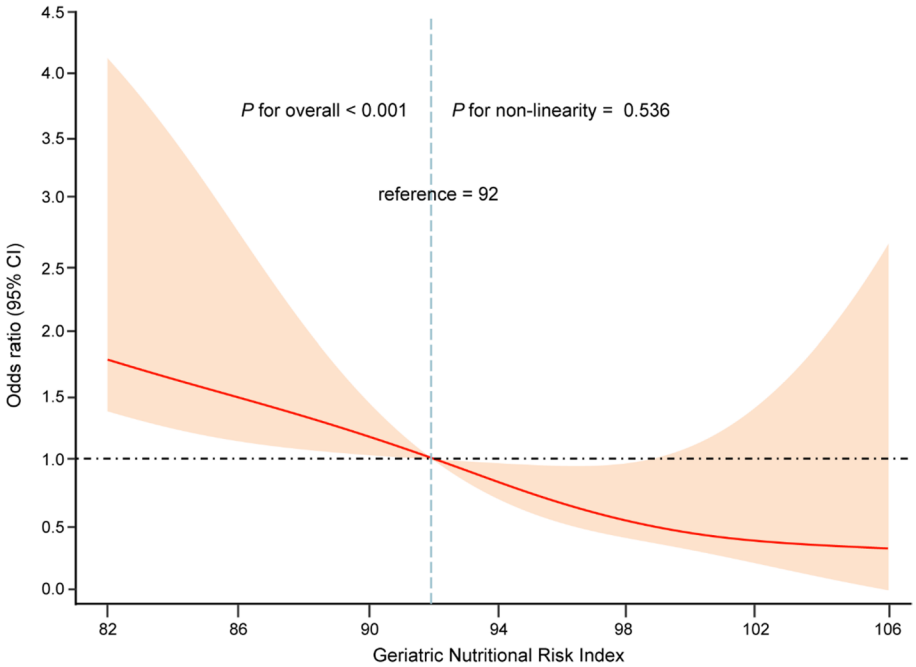

Fig. 2 Dose–effect relationship between the GNRI score and post-stroke myocardial injury. Multivariate adjusted odds ratio for post-stroke myocardial injury is based on restricted cubic spline analysis with four knots. Solid lines represent point estimates of the relationship between the GNRI score and post-stroke myocardial injury, while dashed lines indicate the 95% CI estimation. GNRI, geriatric nutritional risk index; CI, confidence interval

vs. high GNRI) and found that low GNRI score was associated with an increased risk of incident post-stroke myocardial injury in the univariate analysis (OR: 2.74; 95% CI: 1.74–4.33; $P<0.001$). In all multivariate models adjusting confounders, patients in the low GNRI group had greater risk of incident post-stroke myocardial (OR range: 2.88–3.25, $P<0.01$ for all) (Table 3, Supplementary Table 4). After PSM, the baseline characteristics between the low GNRI and high GNRI groups were generally well balanced, with SMD < 0.1 for most covariates except for albumin and triglycerides (Table 2, Fig. 4). Following PSM adjustment ($n=202$), low GNRI score remained independently associated with incident post-stroke myocardial injury (OR: 3.59; 95% CI: 1.93–6.67; $P<0.001$) (Table 3, Supplementary Table 5).

Subgroup analyses

Among 116 elderly patients with low GNRI score, 66 (56.9%) were male, 60 (51.7%) presented hypertension, 30 (25.9%) were with NIHSS greater than 4, 23 (19.8%) exhibited increased blood glucose levels (≥7.0 mmol/L). An increased risk of low GNRI score associated with incident post-stroke myocardial injury was observed in both female (OR: 3.00; 95% CI: 1.31–4.89; $P=0.009$) and male subgroups (OR: 2.25; 95% CI: 1.50–3.66; $P=0.007$). The relationship between low GNRI score and incident post-stroke myocardial injury was significant in patients with (OR: 3.70; 95% CI: 1.67–5.21; $P=0.001$) and without (OR: 3.45; 95% CI: 1.31–4.19; $P=0.017$) hypertension. In patients with blood glucose levels ≥ 7.0 mmol/L, low GNRI score was significantly associated with incident post-stroke myocardial injury (OR: 2.49; 95% CI: 1.81–3.61; $P=0.009$). A significant interaction and increased risk of low GNRI score for predicting incident post-stroke myocardial injury were only significant in the NIHSS > 4 group (OR: 2.76; 95% CI: 1.60–4.93; $P=0.012$; P value for interaction = 0.016). Additionally, an increased risk of low GNRI score associated with incident post-stroke myocardial injury was identified among the elderly with large artery atherosclerosis stroke (OR: 3.32; 95% CI: 1.61–5.84; $P=0.001$) (Fig. 5).

Discussion

In this cohort of elderly patients diagnosed with first-ever ischemic stroke who had no prior history of cardiovascular comorbidities, we investigated the association between nutritional risk and incident post-stroke myocardial injury. Malnutrition risk, evaluated by GNRI score, was common and exhibited a negative dose–response relationship with post-stroke myocardial injury. Low GNRI score on admission was identified as an independent risk factor for post-stroke

Table 2 Comparison of the subject baseline characteristics of the groups of "Low GNRI" and "High GNRI"

Characteristic	Unadjusted Sample ($n=377$)				PSM adjusted (1:1) ($n=202$)			
	Low GNRI ($n=116$)	High GNRI ($n=261$)	*P* value	SMD	Low GNRI ($n=101$)	High GNRI ($n=101$)	*P* value	SMD
Post-stroke myocardial injury (%)	57 (49.1)	68 (26.1)	< 0.001	0.462	49 (48.5)	31 (30.7)	0.010	0.555
Demographics								
Age, y	69.0 (66.5,76.0)	70.0 (67.0,75.0)	0.433	0.110	69.1 (65.7, 76.2)	69.0 (66.3, 75.9)	0.933	0.008
Male (%)	66 (56.9)	144 (55.2)	0.756	0.035	54 (53.5)	51 (50.5)	0.673	0.060
Height, cm	165.0 (160.0, 170.0)	165.0 (160.0, 171.0)	0.532	0.080	165.0 (160.0, 172.0)	168.0 (160.0, 171.0)	0.950	0.006
Weight, kg	65.0 (57.8, 73.0)	70.0 (60.0, 75.0)	0.041	0.238	65.0 (58.0, 73.0)	65.0 (60.0, 75.0)	0.957	0.010
BMI, kg/m^2	24.1 (22.0, 25.7)	25.1 (22.9, 26.7)	0.003	0.326	24.2 (22.2, 25.7)	24.0 (21.2, 25.8)	0.983	0.004
SBP, mmHg	135.5 (122.0, 147.0)	135.0 (124.0, 147.0)	0.711	0.107	135.0 (122.0, 147.0)	139.0 (126.0, 149.0)	0.603	0.032
DBP, mmHg	81.0 (73.0, 87.3)	80.0 (73.0, 87.0)	0.459	0.067	80.0 (73.0, 87.0)	81.0 (75.0, 89.0)	0.510	0.057
Current smoking (%)	36 (31.0)	87 (33.3)	0.660	0.050	32 (31.7)	29 (28.7)	0.646	0.064
Alcohol (%)	31 (26.7)	76 (29.1)	0.634	0.054	24 (23.8)	23 (22.8)	0.868	0.023
Previous medical history								
Hypertension (%)	60 (51.7)	137 (52.5)	0.891	0.015	52 (51.5)	50 (49.5)	0.778	0.040
Diabetes mellitus (%)	30 (25.9)	74 (28.4)	0.618	0.057	27 (26.7)	26 (25.7)	0.873	0.022
COPD (%)	9 (7.8)	9 (3.5)	0.070	0.161	3 (3.0)	4 (4.0)	0.718	0.058
Peripheral vascular disease	18 (15.5)	59 (22.6)	0.115	0.196	17 (16.8)	19 (18.8)	0.373	0.029
Renal dysfunction[a]	3 (2.6)	5 (1.9)	0.976	0.042	2 (2.0)	2 (2.0)	1.000	0.000
Clinical characteristics								
Admission NIHSS score, unit	6.0 (3.0, 9.0)	3.0 (2.0, 7.0)	< 0.001	0.253	5.0 (3.2, 7.9)	4.9 (2.3, 8.1)	0.953	0.017
Admission GCS score, unit	12.0 (10.0, 13.0)	13.0 (12.0, 15.0)	0.002	0.159	13.0 (11.0, 14.0)	13.0 (12.0, 14.0)	0.632	0.062
Dysphagia (%)	17 (14.7)	43 (16.5)	0.656	0.051	16 (15.8)	13 (12.9)	0.547	0.081
TOAST stroke subtype (%)[b]								
Large-artery atherosclerosis	45 (38.8)	117 (44.8)	0.264	0.043	40 (39.6)	42 (41.6)	0.788	0.040
Small-vessel occlusion	11 (9.5)	12 (4.6)			7 (6.9)	7 (6.9)		
Stroke of other determined etiologies	14 (12.1)	34 (13.0)			13 (12.9)	15 (14.9)		
Stroke of undetermined etiology	46 (39.6)	98 (37.6)			38 (37.6)	35 (34.7)		
OCSP stroke subtype (%)								
Lacunar infarct	11 (9.5)	12 (4.6)	0.200	0.077	7 (6.9)	7 (6.9)	0.725	0.023
Partial anterior circulation infarct	46 (39.6)	110 (42.2)			38 (37.6)	40 (39.6)		
Total anterior circulation infarct	27 (23.3)	76 (29.1)			24 (23.8)	25 (24.8)		
Posterior circulation infarct	32 (27.6)	63 (24.1)			32 (31.7)	29 (28.7)		
Medications								
Intravenous thrombolysis (%)	8 (6.9)	23 (8.8)	0.532	0.076	6 (5.9)	7 (6.9)	0.234	0.047
Endovascular treatment (%)	10 (8.6)	7 (2.7)	0.010	0.212	5 (5.0)	6 (5.9)	0.757	0.046
Laboratory findings								
Hemoglobin, g/L	133.5 (120.0, 147.3)	132.0 (121.0, 146.0)	0.980	0.014	131.0 (116.0, 147.0)	132.0 (122.0, 145.0)	0.752	0.013
Albumin, g/L	39.7 (37.5, 42.60)	40.8 (38.0, 42.9)	0.015	0.186	39.2 (37.7, 42.6)	40.6 (38.0, 42.7)	0.038	0.116
Blood glucose, mmol/L	5.2 (4.7, 6.4)	5.3 (4.8, 6.8)	0.414	0.021	5.2 (4.7, 6.2)	5.3 (4.8, 6.4)	0.469	0.028
Triglycerides, mmol/L	1.2 (0.9, 1.6)	1.3 (0.9, 1.8)	0.304	0.212	1.3 (0.9, 1.6)	1.2 (0.9, 1.6)	0.089	0.112
Total cholesterol, mmol/L	4.2 (3.7, 5.1)	4.4 (3.8, 5.2)	0.347	0.099	4.1 (3.6, 5.1)	4.4 (3.8, 5.1)	0.321	0.095
HDL-C, mmol/L	1.1 (0.8, 1.4)	1.1 (0.9, 1.4)	0.206	0.136	1.1 (0.9, 1.4)	1.1 (0.9, 1.3)	0.935	0.026
LDL-C, mmol/L	2.7 (2.2, 3.3)	2.7 (2.2, 3.4)	0.762	0.021	2.7 (2.2, 3.3)	2.9 (2.3, 3.3)	0.444	0.058

The data are presented as the median (interquartile range), mean (standard deviation), or n (%). PSM was performed to achieve balances on baseline characteristics between "Low GNRI" and "High GNRI" groups. SMD < 0.1 indicated a minor acceptable deviation

Abbreviations: *GNRI* Geriatric Nutritional Risk Index, *PSM* Propensity score matching, *SMD* Standardized mean difference, *BMI* Body mass index, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure, *COPD* Chronic obstructive pulmonary disease, *NIHSS* National Institutes of Health Stroke Scale, *GCS* Glasgow Coma Scale, *TOAST* Trial of Org 10,172 in Acute Stroke Treatment, *OCSP* Oxfordshire Community Stroke Project, *HDL-C* High-density lipoprotein cholesterol, *LDL-C* Low-density lipoprotein cholesterol

[a] Creatinine > 177 μmol/L

[b] Under TOAST, the subgroup of cardioembolism is excluded

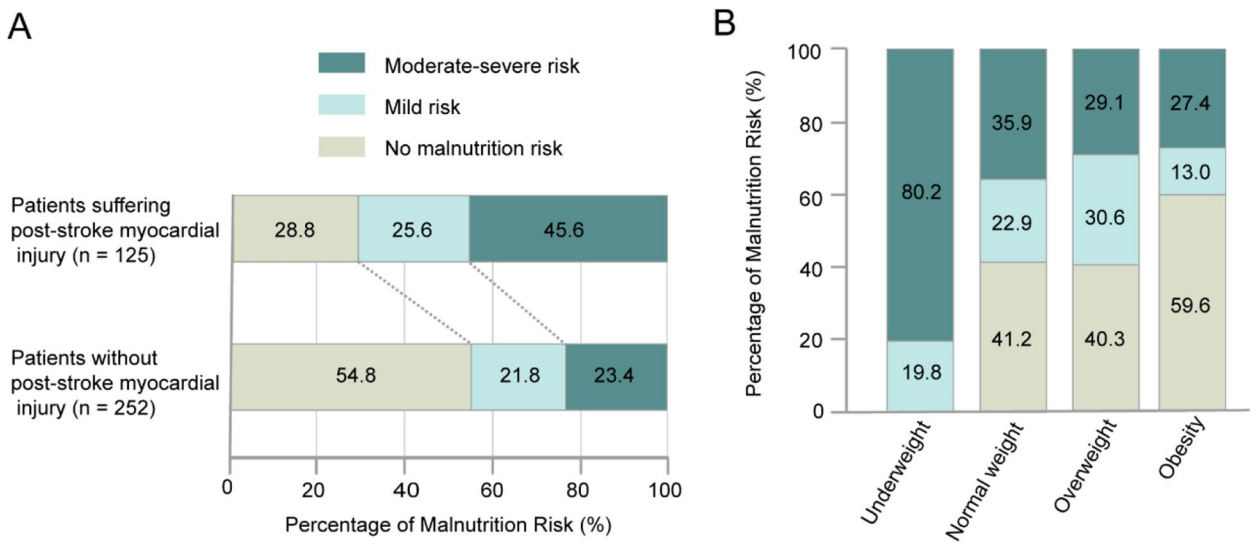

Fig. 3 Percentage of malnutrition risk according to GNRI score and BMI. GNRI, geriatric nutritional risk index; BMI, body mass index

Table 3 Association of low GNRI score with post-stroke myocardial injury

Analysis method	OR	95% CI	*P* value
Logistic regression analysis ($n=377$)			
Model 1 (univariate model)[a]	2.74	1.74–4.33	< 0.001
Model 2 (demographic and previous patient-related covariates adjusted)[b]	3.22	1.96–5.29	< 0.001
Model 3 (stroke-related covariates adjusted)[c]	3.10	1.93–4.97	0.005
Model 4 (laboratory indicators adjusted)[d]	2.88	1.76–4.70	0.002
Model 5 (fully adjusted)[e]	3.25	1.93–5.48	< 0.001
Propensity score analysis			
Model PSM ($n=202$)[f]	3.59	1.93–6.67	< 0.001

Abbreviations: *GNRI* Geriatric Nutritional Risk Index, *OR* Odds ratio, *CI* Confidence interval, *PSM* Propensity score matching

[a] Model 1 was an univariate regression model

[b] Model 2 included low GNRI score, age, male, height, weight, BMI, SBP, DBP, current smoking, alcohol, hypertension, diabetes mellitus, COPD, peripheral vascular disease, and renal dysfunction

[c] Model 3 included low GNRI score, admission NIHSS score, admission GCS score, dysphagia, TOAST stroke subtype, OCSP stroke subtype, intravenous thrombolysis, and endovascular treatment during hospitalization

[d] Model 4 included low GNRI score, hemoglobin, albumin, blood glucose, triglycerides, total cholesterol, HDL-C, and LDL-C

[e] Model 5 was adjusted for all the potential confounders. Univariate and multivariate results are shown in Supplementary Table 4

[f] 202 patients were matched (1:1) using propensity score approach. Univariate result is shown in Supplementary Table 5

myocardial injury. Our findings suggest that risk of malnutrition may be a potentially modifiable risk factor and therapeutic target for medical intervention.

Despite its high prevalence and general importance, malnutrition risk is typically underappreciated in clinical practice. In our study of elderly patients with first-ever ischemic stroke and no prior history of cardiovascular comorbidities, approximately half of patients were identified with malnutrition risk on admission based on GNRI score. The overall incidence of malnutrition risk was aligned with previous rates of 15.99% to 57.86% in stroke patients [13, 22]. Prior studies have reported that the incidence of moderate to severe malnutrition risk after AIS ranged from 1.95% to 35.30% [22, 23]. Similarly, the event rate for moderate to severe malnutrition risk was substantial in our study. Additionally, given the high prevalence of obesity, we found that malnutrition risk was prevalent in a substantial proportion of overweight and obese patients. It is a reminder that obese patients may suffer from an impairment of energy utilization with fat mass, leading to the loss of lean mass to maintain organism homeostasis [24–26]. Therefore, nutritional risk needs to be evaluated in older patients with AIS regardless of BMI, including those who are overweight or obese.

Several studies have demonstrated that the predictive power of objective malnutrition score, GNRI score, is comparable with that of the common criteria for evaluating nutritional risk, such as NRS 2002 [23] and MNA tools [27]. Given high precision, clinical applicability, and reasonable cost-effectiveness, the objective malnutrition score warrants particular consideration. A national, multicenter, prospective registry study in China revealed that the GNRI score was closely associated with death and

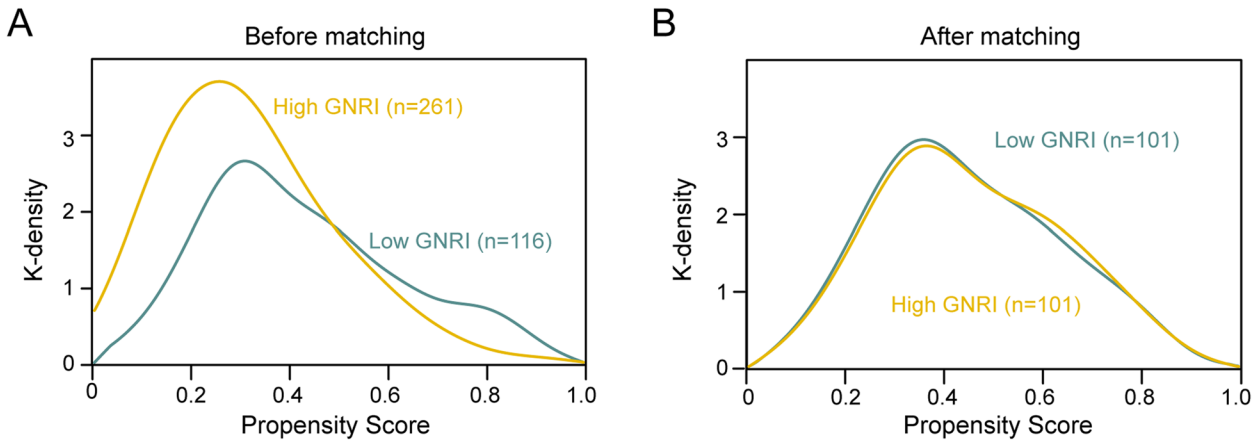

Fig. 4 Distribution of propensity scores of patients with low GNRI and high GNRI before (**A**) and after (**B**) matching. GNRI, geriatric nutritional risk index

Subgroup	Low GNRI and post-stroke myocardial injury cases, n	High GNRI and post-stroke myocardial injury cases, n	Adjusted OR (95%CI)	*P* value	*P* value for interaction
Overall	**116 (57)**	**261 (68)**	**3.25 (1.93-5.48)**	**<0.001**	
Sex					
Female	50 (20)	117 (23)	3.00 (1.31-4.89)	0.009	**0.600**
Male	66 (37)	144 (45)	2.25 (1.50-3.66)	0.007	
Hypertention					
No	56 (23)	124 (22)	3.45 (1.31-4.19)	0.017	**0.878**
Yes	60 (34)	137 (46)	3.70 (1.67-5.21)	0.001	
NIHSS					
≤ 4	86 (34)	182 (55)	2.47 (0.95-3.84)	0.109	**0.016**
> 4	30 (23)	79 (13)	2.76 (1.60-4.93)	0.012	
Blood glucose, mmol/L					
< 7.0	93 (39)	201 (49)	2.05 (1.59-2.87)	<0.001	**0.102**
≥ 7.0	23 (18)	60 (19)	2.49 (1.81-3.61)	0.009	
TOAST classification					
LAA	45 (23)	117 (28)	3.32 (1.61-5.84)	0.001	**0.755**
SVO	11 (3)	12 (3)	1.32 (0.76-3.24)	0.901	
SOE	14 (8)	34 (10)	3.20 (0.89-4.63)	0.077	
SUE	46 (23)	98 (27)	2.63 (1.27-5.45)	0.009	

Fig. 5 Subgroup analyses of the association of low GNRI score with the risk of post-stroke myocardial injury. GNRI, geriatric nutritional risk index; OR, odds ratio; CI, confidence interval; NIHSS, National Institutes of Health Stroke Scale; TOAST, Trial of Org 10,172 in Acute Stroke Treatment;LAA, large artery atherosclerosis; SVO, small vessel occlusion; SOE, stroke of other determined etiologies; SUE, stroke of undetermined etiology

major disability after stroke [13]. In addition, an elevated malnutrition risk, as assessed by the GNRI score, had an increased risk of mortality and future major cardiovascular events (MACE) in individuals with acute coronary syndrome [12], and exhibited a higher probability of poststroke depression [22].

In our study, nutritional risk on admission, as indicated by the GNRI score, exhibited a tight association with the occurrence of post-stroke myocardial injury in older patients with first-ever ischemic stroke and no prior history of cardiovascular comorbidities, particularly in patients with moderate to severe malnutrition risk. The negative relationship between the GNRI score and post-stroke myocardial injury remained consistent, even after adjusting for confounding variables, suggesting high stability of the predictive ability. Furthermore, an increased risk of low GNRI score for post-stroke myocardial injury was observed in subgroup analyses, particularly in patients with moderate to severe neurologic deficits (NIHSS $^{>}$ 4). These results indicated that a deteriorating nutritional status on admission, as indicated by the GNRI score, had more significant risk of experiencing post-stroke myocardial injury.

How does malnutrition risk on admission influence post-stroke myocardial injury? The intrinsic mechanism underpinning the association remains elusive, but several plausible explanations exist. GNRI score encompasses both serum albumin and anthropometric factors (weight and height). Previous studies have shown that albumin levels are associated with the risk of all-cause death in patients with ischemic stroke [28]. Albumin can affect both adaptive and innate immune responses [29]; thus, hypoalbuminemia on admission may aggravate inflammation by suppressing the immune function [30, 31], ultimately increasing the risk of post-stroke myocardial injury. In addition, serum albumin functions as a major antioxidant by exhibiting glutathione peroxidase activity and scavenging reactive oxygen species in plasma [32, 33], which may protect the myocardium. Importantly, ischemic stroke may decrease serum albumin synthesis and increase its catabolism, thereby resulting in a decrease in the total albumin levels [34, 35]. Albumin can facilitate the binding and transport of inflammatory substances, modulating inflammation and inhibiting cytokine storm [36–38]. Thus, the GNRI score boasted a superior diagnostic value for malnutrition risk and performed efficiently in stratifying patients at higher risk of developing post-stroke myocardial injury. Personalized nutrition supplementation should be implemented thereafter in patients identified as at risk for malnutrition or who are already malnourished.

This study has several potential limitations. First, we cannot draw rigorous causality conclusions between nutritional risk and post-stroke myocardial injury due to the retrospective nature of this study. This definitive causal association should be further explored in large prospective cohorts. Second, as a single-center cohort, our findings may not be appropriate for generalizability to other medical centers. Third, the assessment of nutritional status should be comprehensively performed and documented using the diagnostic criteria for malnutrition. We cannot discern the differences in predictive ability upon comparison GNRI score with the criteria for malnutrition. Future studies might be needed to explore the differences. Fourth, although all stroke patients underwent review of cardiac history, transthoracic echocardiography (TTE), and electrocardiogram (ECG) for cardiac evaluation, cardioembolic stroke can not be excluded. Transesophageal echocardiography (TEE), cardiac CT, or cardiac MRI might be more sensitive for screening the source of emboli. Fifth, although we had controlled for numerous known important confounders, we cannot completely exclude the unmeasured residual confounding, such as medications, fluid infusion, brain natriuretic peptide (BNP) or N-terminal pro-brain natriuretic peptide (NT-proBNP). Finally, several patients were excluded from our study because of the missing data required for calculating the malnutrition score, which may introduce potential bias.

Conclusion

In conclusion, moderate to severe malnutrition risk on admission, as indicated by the GNRI score, was significantly associated with a higher risk of developing post-stroke myocardial injury in older patients with first-ever ischemic stroke who had no prior history of cardiovascular comorbidities. Our findings underscore the importance of early screening for malnutrition risk and appropriate nutritional intervention in neurogenic cardiac injury. Nevertheless, the efficacy of malnutrition score-targeted treatment for post-stroke myocardial injury needs to be validated by further prospective studies.

Abbreviations

GNRI	Geriatric nutritional risk index
RCS	Restricted cubic spline
PSM	Propensity score matching
IQR	Interquartile range
OR	Odds ratio
CI	Confidence interval
NRS 2002	Nutritional risk screening 2002
MNA	Mini nutritional assessment
SGA	Subjective global assessment
AIS	Acute ischemic stroke
STROBE	STrengthening the Reporting of OBservational studies in Epidemiology
CT	Computerized tomography
MRI	Magnetic resonance imaging
TIA	Transient ischemic attack

BMI	Body mass index
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
COPD	Chronic obstructive pulmonary disease
NIHSS	National Institutes of Health Stroke Scale
GCS	Glasgow Coma Scale
TOAST	Trial of Org 10,172 in Acute Stroke Treatment
OCSP	Oxfordshire Community Stroke Project
SD	Standard deviations
IQR	Interquartile range
SMD	Standardized mean difference
MACE	Major cardiovascular events
BNP	Brain natriuretic peptide
NT-proBNP	N-terminal pro-brain natriuretic peptide
TTE	Transthoracic echocardiography
ECG	Electrocardiogram
TEE	Transesophageal echocardiography

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-05796-x.

Supplementary Material 1.

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Not applicable.

Authors' contributions
S.S. and L.Z. conceptualized and designed the study. L.W. conducted the statistical analysis. M.N. and H.Y. collected the data and interpreted the data. M.N. and F.Z. drafted and revised the manuscript. All authors reviewed the manuscript.

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

Declarations

Ethics approval and consent to participate
Study procedures were performed in accordance with the Declaration of Helsinki ethical principles for medical research involving human subjects. The study was approved by the Medical Ethics Committee of The Affiliated Hospital of Xuzhou Medical University (reference No. XYFY2022-YL117-01), and the informed consent was waived due to the retrospective nature of the cohort study.

Competing interests
The authors declare no competing interests.

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