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Preoperative geriatric nutritional risk index predicts prognosis and postoperative complications in elderly patients undergoing non-cardiac surgery: a retrospective cohort study

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Abstract

Background Little evidence on the association between geriatric nutritional risk index (GNRI) with prognosis and postoperative complications was observed. This study examined the potential prognostic value of GNRI in elderly patients undergoing non-cardiac surgery.

Methods This retrospective analysis was data retried from the Chinese elderly patients' perioperative database (CEPPD), a multicenter registry, from June 1st, 2012 to August 15th, 2019. Patients were categorized into at-risk group (GNRI ≤ 98) and no-risk group (GNRI > 98). Kaplan–Meier analysis and multivariate Cox proportional hazard regression were used to explore the association between GNRI and overall survival (OS). Multivariate logistic regression and linear regression were used to explore the association of the GNRI with postoperative complications. A propensity score matching (PSM) analysis was also conducted at a 1:1 ratio using the greedy nearest-neighbor method.

Results The final analysis included 28,762 elderly patients undergoing non-cardiac surgery. The PSM cohort included 7,063 patients in each group. The 1-year OS rate was 90.2% in the at-risk group vs. 96.3% in the no-risk group ($P < 0.001$). In Kaplan-Meier analysis, OS was significantly shorter in the at-risk group ($P < 0.001$ for both before matching and PSM). In multivariable Cox regression, at-risk GNRI was independently associated with OS in both the overall analysis (HR: 1.682; 95% CI: 1.502–1.882; $P < 0.001$) and the PSM cohort (HR: 1.501; 95% CI: 1.316–1.711;

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$P < 0.001$). At-risk GNRI was also independently associated with postoperative heart injury, acute renal injury, pulmonary infection, surgical site infection, intensive care unit (ICU) admission, longer ICU length of stay (LOS), and longer postoperative LOS.

Conclusions Preoperative at-risk GNRI was associated with poor survival outcome and higher risk of postoperative complications in elderly patients undergoing non-cardiac surgery.

Keywords Noncardiac surgery, Elderly patients, Geriatric nutritional risk index (GNRI), Complication, Prognosis

Introduction

With the ageing of the general population, the number of elderly patients undergoing surgery has been increasing rapidly [1]. For example, percentage of the elderly people (≥65 of age) in the Chinese patients undergoing non-cardiac surgery increased from 12.6% in 2009 to 20.1% in 2019. Elderly patients represent a major challenge to peri-operative management since they often have multiple co-morbid conditions, including hypertension, diabetes, cardiovascular and cerebrovascular diseases, and respiratory dysfunction [2, 3], which in turn are associated with malnutrition [4, 5]. Disease-related malnutrition has been associated with increased morbidity and mortality in a variety of settings [4–7]. Several studies have revealed that preoperative malnutrition status is a risk factor for postoperative complications and worse outcomes [8, 9]. Although the prevalence of hospital malnutrition is as high as approximately 20–50%, its importance is frequently underestimated in clinical practice due to the lack of acknowledgement, as well as the lack of a standard nutritional risk screening tool [10, 11].

Geriatric nutritional risk index (GNRI) is an elderly-specific index that has been proposed to assess the nutrition-related risk of morbidity and mortality for elderly patients in hospital [12, 13]. This index was first reported by Bouillanne et al. [14]. The GNRI is also used for prognosis of chronic diseases [15–17], and recently, it has been reported as a useful screening tool to predict prognosis for not only chronic diseases but also surgical procedures. Most researches focused on the prognostic value of GNRI in elderly patients with specific surgical procedure, including esophageal surgery, gastrointestinal surgery, pancreatoduodenectomy, bladder cystectomy, nephrectomy and total joint arthroplasty [18–23]. Nevertheless, to date there is no reports focus on non-cardiac patients as a whole body, and the clinical value is limited because only a small cohort of patients have been assessed.

Therefore, in this study, we conducted a retrospective analysis based on a relatively large registry database to examine whether preoperative GNRI is associated with 1-year survival and postoperative complications in elderly patients who underwent non-cardiac surgery regardless of specific procedures.

Methods

Study design and participants

Patient data were derived from the Chinese elderly patients' perioperative database (CEPPD), a registry database of in-patients undergoing surgery at Chinese PLA General Hospital. An electronic search was conducted to retrieve all elderly patients (65 years or older) undergoing non-cardiac surgery under general anesthesia, either with or without regional anesthesia, during a period from June 1st, 2012 to August 15th, 2019. The exclusion criteria included: (1) duration of surgery ≤ 60 min; (2) American society of anesthesiologists (ASA) classification of V; and (3) missing data on sex, body weight, height, or albumin prior to surgery. In patients with multiple surgeries within the index period, only the first surgery was included in the final analysis.

The study was adhered to the Declaration of Helsinki. This study was approved by the Ethics Committee Board of the First Medical Center of Chinese PLA General Hospital (No.S2019-311–03). The need for consent to participate was waived by the Institutional Review Board of the First Medical Center of Chinese PLA General Hospital as the study was retrospective, and all data were anonymized before analysis. The reporting followed the Reporting of Studies Conducted Using Observational Routinely-Collected Health Data (RECORD) statement [24].

Data collection

Preoperative variables included age, sex, body mass index (BMI), ASA classification, smoking status (currently smoking versus not), and major comorbidities, e.g., hypertension, diabetes, coronary heart disease, arterial fibrillation, myocardial infarction, cerebrovascular disease, peripheral vascular disease, renal insufficiency (glomerular filtration rate, GFR < 60 mL/(min·1.73 m2)), chronic obstructive pulmonary disease (COPD), and malignant tumor. Laboratory results included fasting blood glucose, creatinine level, hemoglobin, platelet, albumin, total bilirubin, and prothrombin time. Current medications included antihypertensive, lipid lowering agents, hypoglycemics, antiplatelets, and anticoagulants. Surgery-related variables included surgical type (emergency or elective), surgical procedure, duration of procedures, estimated blood loss, blood transfusion, and use of volatile anesthetic agent, opioid, dexmedetomidine, glucocorticoid, non-steroid anti-inflammatory drugs (NSAIDs) during surgery. Postoperative complications during hospitalization included pulmonary infection, surgical site infection (SSI), sepsis, heart injury (arrhythmia, heart failure, myocardial infarction, cardiac arrest), acute renal injury (AKI), and stroke, as defined according to consensus definitions [25]. Other measures included admission and length of stay (LOS) in intensive care unit (ICU), postoperative LOS, readmission and reoperation within 30 days from discharge. OS was verified using the Chinese Center for Disease Control and Prevention database in all subjects. The last follow-up date was January 15th, 2021.

Nutritional assessment by GNRI

GNRI was calculated using the following formula: 1.489 × serum albumin concentration (g/L) + 41.7 × present weight (PW)/ideal weight (IW]), as previously reported [26]. IW was calculated as: height (cm) -100 - ([height (cm) − 150]/4) for men, and height (cm) − 100 - ([height (cm) − 150]/2.5) for women. The PW/IW ratio was regarded as 1.0 if PW exceeded IW [27]. In the present study, we categorized patients based on GNRI into 2 groups: at-risk (GNRI ≤ 98) group and no-risk (GNRI > 98) groups.

Statistical analysis

Normally distributed continuous variables were compared between patients with at-risk versus no-risk GNRI (≤ 98 versus > 98) using Student' s t-test for independent samples, and presented as mean (standard deviation, SD). Continuous data that were not normally distributed were compared using Mann–Whitney's test, and presented as median (interquartile range, IQR]. Categorical variables were compared using the $\chi 2$ test or Fisher's exact test as appropriate, and presented as number and percentage.

Survival analysis was conducted using the Kaplan–Meier method, followed by the log-rank test. Multivariate Cox proportional hazards regression analysis was conducted to identify risk factors associated with OS. The results of the regression analysis are shown as hazard ratio (HR) and 95% confidence interval (CI).

A propensity score matching (PSM) analysis was conducted to compare OS and postoperative complications between patients with at-risk versus no-risk GNRI. The factors included in the propensity score calculation were based on the results of a logistic regression of GNRI category (at-risk versus no-risk) as the dependent variable, and included age, sex, ASA classification, smoking status, hypertension, coronary heart disease, arterial fibrillation, myocardial infarction, cerebrovascular disease, renal insufficiency, COPD, malignant tumor, current medications, key lab results, and surgery-related variables. The PSM was conducted at a 1:1 ratio using the greedy nearest-neighbor method, with a caliper size of 0.2. After obtaining matched data, Kernel density plots and standardized mean difference (SMD) were applied to assess the balance of covariates between the two groups. SMD < 0.2 was considered acceptable. Multivariate Cox regression was also conducted in the PSM cohort to examine the impact of GNRI status on OS.

Subgroup analysis was conducted based on age (≤ 75 and > 75 years), sex, hypertension, coronary heart disease, and malignant tumor. Multivariate Cox regression conducted in each subgroup to calculate the adjusted HR before matching. A restricted cubic spline (RCS) was used to further delineate the profile of association between GNRI and OS.

Multivariable logistic regression and linear regression were conducted to assess whether at-risk GNRI was significantly associated with postoperative complications before matching. The postoperative complications included those that showed significant differences between the two GNRI groups before and after PSM. Results are shown as odds ratios (OR) and their 95% CI. A RCS was used to further delineate the link between GNRI and postoperative complications.

All statistical analyses were conducted using IBM Statistical Package for Social Sciences (SPSS) Statistics (version 28.0; IBM Corp., New York, NY, USA) and R program (version 4.3.1; R Foundation for Statistical Computing, Vienna, Austria). For R, we used the pROC, MatchIt, car, survival, survminer, survey, stats, ggplot 2, tableone, forestplot, rms, and openxlsx packages. $P < 0.05$ (two-sided) was considered statistically significant.

Results

Study population

We screened a total of 48,313 elderly patients who underwent non-cardiac surgery from June 1st, 2012 to August 15th, 2019. Figure 1 illustrates the flow diagram of patient selection. After applying the inclusion and exclusion criteria, the final analysis included 28,762 patients (median age: 70 [67, 74] years, 15,686 (54.5%) were men). Among these elderly patients, the relatively common types of surgeries were as follows: 11,515 cases (40.0%) underwent intra-abdominal surgery, 3,687 cases (12.8%) underwent urologic or gynecologic surgery, and 3,322 cases (11.5%) underwent joint arthroplasty. The 1-year mortality rate was 5.8% (1,664/28,762). The mean baseline GNRI value was 99.8 (6.7).

Demographic and baseline characteristics of the at-risk group (GNRI ≤ 98, n = 9,937, 34.5%) and no-risk group (GNRI > 98, n = 18,825, 65.5%) are shown in Table 1. The two groups differed significantly in age, sex, BMI, ASA classification, surgical procedures, duration of procedures, hemoglobin, albumin, and blood transfusion. The

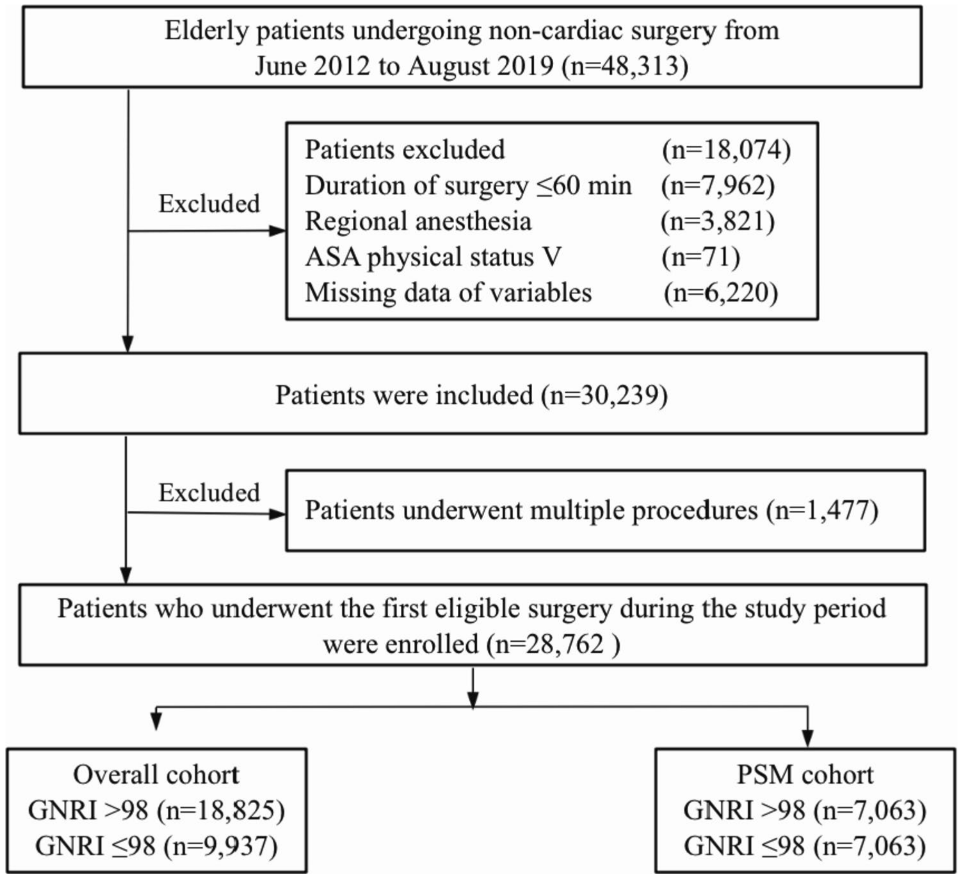


Fig. 1 Study flow diagram. ASA, American Society of Anesthesiologists; PSM, propensity score matching

at-risk group also had more cardiovascular and cerebrovascular comorbidities (arterial fibrillation, cerebrovascular disease, peripheral vascular disease), renal insufficiency, COPD, and malignant tumor, but lower use of antihypertensive, hypoglycemics, and antiplatelets.

In the PSM cohort, all demographic and baseline characteristics were well balanced, except for BMI and albumin (Table 1).

Overall survival

The OS of patients with at-risk GNRI was significantly worse than that of patients with no-risk GNRI (log-rank test, $p < 0.001$; Fig. 2A). The 3-month overall mortality rate was 0.5% (103/18825) in the no-risk group, and 2.1% (211/9937) in the at-risk group ($P < 0.001$). The 1-year overall mortality rate was 3.7% (693/18825) in the no-risk group and 9.8% (971/9937) in the at-risk group ($P < 0.001$). In the multivariate Cox regression analysis, at-risk GNRI was independently associated with poor OS (aHR: 1.682; 95% CI: 1.502–1.882; $P < 0.001$) (Table 2).

The PSM included 7063 patients in each group. The distribution of propensity scores among the two groups is graphically displayed by kernel density estimation before and after PSM (Fig. 3A, B). In the PSM cohort, the mean (SD) propensity scores was similar between the at-risk group [0.40 (0.20)] and the no-risk group [0.40 (0.19)], and all confounders, except for BMI and albumin, were well balanced between the two groups (SMD < 0.1; Table 1). In Kaplan-Meier analysis, at-risk GNRI was significantly associated with a decreased 1-year OS and 3-month OS (both $P < 0.001$; Fig. 2B). In the multivariable Cox regression in the PSM cohort, at-risk GNRI was associated with 1-year OS (HR: 1.564; 95% CI: 1.372–1.784; $P < 0.001$; Table 2).

Subgroup analysis

To further explore the clinical significance of at-risk GNRI in the surgery prognosis of patients with hypertension, coronary heart disease, and malignant tumors. Subgroup analysis according to age, sex, hypertension, coronary heart disease, and malignant tumor are shown in Fig. 4. At-risk GNRI was associated with poor OS regardless of age [≤75 years: HR (95% CI): 1.641 (1.445, 1.864), $P < 0.001$; >75 years: HR (95% CI): 1.852 (1.451, 2.364), $P < 0.001$], and sex [men: HR (95% CI): 1.641 (1.445, 1.864), $P < 0.001$; women: HR (95% CI): 1.852 (1.451, 2.364), $P < 0.001$]. At-risk GNRI was correlated with poor OS in patients with hypertension [HR (95%

Table 1 Demographic and baseline characteristics of overall cohort and PSM cohort (patients from 2012–2019)

	Overall cohort (*N* = 28,762)				**PSM cohort (1:1) (*N* = 14,126)**			
Characteristic	**no-risk (18,825)**	**at-risk (9,937)**	***P*-value**	**SMD**	**no-risk (7,063)**	**at-risk (7,063)**	***P*-value**	**SMD**
Demographics								
Age, year†	69.00 [67.00, 73.00]	71.00 [67.00, 76.00]	< 0.001	0.368	71.45 (5.10)	71.31 (5.05)	0.1	0.028
Male sex (%)†	9895 (52.6)	5791 (58.3)	< 0.001	0.115	3899 (55.2)	3916 (55.4)	0.787	0.005
BMI, kg/m^2	24.97 [23.12, 27.18]	22.65 [20.20, 25.25]	< 0.001	0.69	24.85 (3.03)	23.12 (3.84)	< 0.001	0.5
ASA classification (%)†			< 0.001	0.251			0.964	0.009
Class I	277 (1.5)	107 (1.1)			92 (1.3)	93 (1.3)		
Class II	15,336 (81.5)	7182 (72.3)			5401 (76.5)	5413 (76.6)		
Class III	3118 (16.6)	2450 (24.7)			1493 (21.1)	1486 (21.0)		
Class IV	94 (0.5)	198 (2.0)			77 (1.1)	71 (1.0)		
Previous medical history								
Current smoking (%)†	2168 (11.5)	1173 (11.8)	< 0.001	0.082	802 (11.4)	810 (11.5)	0.975	0.004
Hypertension (%)†	9006 (47.8)	3766 (37.9)	< 0.001	0.202	2792 (39.5)	2822 (40.0)	0.618	0.009
Diabetes mellitus (%)	4544 (24.1)	2156 (21.7)	< 0.001	0.058	1536 (21.7)	1523 (21.6)	0.806	0.004
CHD (%)†	2293 (12.2)	1166 (11.7)	0.276	0.014	793 (11.2)	818 (11.6)	0.525	0.011
Arterial fibrillation (%)†	275 (1.5)	191 (1.9)	0.004	0.036	127 (1.8)	120 (1.7)	0.7	0.008
MI (%)†	223 (1.2)	160 (1.6)	0.003	0.036	97 (1.4)	105 (1.5)	0.62	0.01
CVD (%)†	1481 (7.9)	854 (8.6)	0.034	0.026	570 (8.1)	581 (8.2)	0.758	0.006
PVD (%)	1522 (8.1)	907 (9.1)	0.003	0.037	567 (8.0)	634 (9.0)	0.046	0.034
Renal insufficiency (%)†	244 (1.3)	222 (2.2)	< 0.001	0.071	140 (2.0)	128 (1.8)	0.498	0.012
COPD (%)†	331 (1.8)	249 (2.5)	< 0.001	0.052	161 (2.3)	142 (2.0)	0.296	0.019
Malignant tumor (%)†	10,666 (56.7)	6354 (63.9)	< 0.001	0.149	4288 (60.7)	4293 (60.8)	0.945	0.001
Antihypertensive (%)†	7591 (40.3)	3379 (34.0)	< 0.001	0.131	2426 (34.3)	2454 (34.7)	0.633	0.008
Lipid lowering agents (%)†	1236 (6.6)	677 (6.8)	0.438	0.01	455 (6.4)	444 (6.3)	0.73	0.006
Hypoglycemics (%)†	2076 (11.0)	808 (8.1)	< 0.001	0.099	596 (8.4)	600 (8.5)	0.928	0.002
Antiplatelets (%)†	1717 (9.1)	780 (7.8)	< 0.001	0.046	552 (7.8)	568 (8.0)	0.64	0.008
Anticoagulants (%)†	1200 (6.4)	1104 (11.1)	< 0.001	0.168	607 (8.6)	621 (8.8)	0.698	0.007
Preoperative laboratory data								
Blood glucose, mmol/L†	5.12 [4.68, 5.88]	5.02 [4.56, 5.89]	< 0.001	0.021	5.51 (1.60)	5.48 (1.87)	0.331	0.016
Last creatinine level, mole/L†	71.70 [61.40, 83.50]	69.70 [58.60, 82.40]	< 0.001	0.004	75.17 (24.06)	74.73 (37.02)	0.396	0.014
Hemoglobin, g/L†	134.00 [125.00, 144.00]	121.00 [109.00, 132.00]	< 0.001	0.855	125.87 (14.85)	126.06 (15.03)	0.447	0.013
Platelet, 10^9/L	209.00 [173.00, 248.00]	211.00 [169.00, 264.00]	< 0.001	0.12	215.77 (65.69)	217.17 (76.59)	0.242	0.02
Albumin, g/L	41.40 [39.80, 43.40]	36.20 [34.30, 37.50]	< 0.001	2.216	41.27 (2.40)	36.28 (2.61)	< 0.001	1.991
Total bilirubin, mole/L†	11.00 [8.60, 14.30]	10.40 [7.70, 15.30]	< 0.001	0.308	16.20 (29.69)	16.75 (30.21)	0.279	0.018
Prothrombin time, s†	16.20 [15.60, 16.90]	16.20 [15.50, 17.00]	< 0.001	0.004	16.33 (2.16)	16.34 (1.52)	0.681	0.007
Surgical and anesthetic factors								
Emergency operation (%)†	301 (1.6)	342 (3.4)	< 0.001	0.118	188 (2.7)	177 (2.5)	0.596	0.01
Surgical procedures (%)†			< 0.001	0.499			0.963	0.023
Trauma surgery	308 (1.6)	463 (4.7)			205 (2.9)	209 (3.0)		
Spine surgery	2037 (10.8)	604 (6.1)			550 (7.8)	548 (7.8)		
Intra-abdominal surgery	6220 (33.0)	5295 (53.3)			3242 (45.9)	3191 (45.2)		
Joint arthroplasty	2431 (12.9)	891 (9.0)			768 (10.9)	789 (11.2)		
Urologic or gynecologic	2833 (15.0)	854 (8.6)			748 (10.6)	762 (10.8)		
Neurosurgery	1040 (5.5)	374 (3.8)			346 (4.9)	334 (4.7)		
Thoracic or vascular	2325 (12.4)	729 (7.3)			600 (8.5)	632 (8.9)		
Other (plastic surgery, etc.)	1631 (8.7)	727 (7.3)			604 (8.6)	598 (8.5)		
Duration of procedures, min†	151.00 [107.00, 211.00]	165.00 [115.00, 229.00]	< 0.001	0.121	176.87 (89.53)	177.53 (90.44)	0.662	0.007
Estimated blood loss, mL†	100.00 [50.00, 200.00]	100.00[50.00, 300.00]	< 0.001	0.083	220.30 (457.05)	222.06 (355.24)	0.799	0.004
Blood transfusion (%)†	2166 (11.5)	1900 (19.1)	< 0.001	0.213	992 (14.0)	1050 (14.9)	0.173	0.023
NSAIDS (%)	14,864 (79.0)	7834 (78.8)	0.821	0.003	5449 (77.1)	5568 (78.8)	0.017	0.041
Glucocorticoid (%)	14,859 (78.9)	7959 (80.1)	0.021	0.029	5584 (79.1)	5616 (79.5)	0.52	0.011
Volatile anesthetic (%)	17,464 (92.8)	9211 (92.7)	0.831	0.003	6507 (92.1)	6583 (93.2)	0.015	0.041

Table 1 (continued)

	Overall cohort (N = 28,762)				PSM cohort (1:1) (N = 14,126)			
Characteristic	**no-risk (18,825)**	**at-risk (9,937)**	***P*-value**	**SMD**	**no-risk (7,063)**	**at-risk (7,063)**	***P*-value**	**SMD**
Opioid dose, mg[†] *	135.00 [105.00, 150.00]	135.00 [105.00, 165.00]	0.083	0.018	130.69 (49.76)	131.72 (49.88)	0.217	0.021
Dexmedetomidine (%)	1731 (9.2)	889 (8.9)	0.499	0.009	636 (9.0)	639 (9.0)	0.953	0.001

The data are shown as the median [IQR], n (%), or mean (SD)

†Variables included in the propensity score

*Including those intraoperatively and postoperatively (up to 7 days after surgery). Morphine 30 mg (per os) = morphine 10 mg (iv) = sufentanil 10 μg (iv) = fentanyl 100 μg (iv) = remifentanil 100 μg (iv) = 100 mg tramadol (iv) = tramadol 200 mg (per os) = oxycodone 15 mg (per os) = dezocine 10 mg (iv) = pethidine 100 mg (iv)

PSM, propensity score matching; SMD, standardized mean difference; BMI, body mass index; ASA, American Society of Anesthesiologists; CHD, coronary heart disease; MI, myocardial infarction; CVD, cerebrovascular disease; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; Hb, hemoglobin; ALB, albumin; TBIL, total bilirubin; PT, prothrombin time; NSAIDs, non-steroid anti-inflammatory drugs

CI): 1.772 (1.477– 2.126), $P<0.001$], coronary heart disease [HR (95% CI): 1.899 (1.364– 2.643), $P<0.001$], and malignant tumor [HR (95% CI): 1.586 (1.411–1.784), $P<0.001$].

Postoperative complications

In univariate analysis, at-risk GNRI was significantly associated with multiple postoperative complications (Table 3). Patients with at-risk GNRI had higher rates of heart injury ($P<0.001$), arrhythmia ($P<0.001$), heart failure ($P<0.001$), AKI ($P<0.001$), pulmonary infection ($P<0.001$), SSI ($P<0.001$), ICU admission ($P<0.001$), and had longer LOS of ICU ($P<0.001$), and longer postoperative LOS ($P<0.001$). In PSM cohort, patients with at-risk GNRI still had higher rates of heart injury ($P<0.001$), arrhythmia ($p=0.009$), heart failure ($P=0.004$), AKI ($P=0.023$), pulmonary infection ($P<0.001$), SSI ($P=0.009$), ICU admission ($P<0.001$), and had longer LOS of ICU ($P=0.01$), and longer postoperative LOS ($P=0.001$). The two groups did not differ in myocardial infarction, cardiac arrest, sepsis, stroke, 30-day readmission or 30-day reoperation after PSM.

In multivariable logistic regression analysis, at-risk GNRI was independently associated with heart injury (OR 1.274, 95% CI 1.089–1.489, $P<0.001$), AKI (OR 1.194, 95% CI 1.043–1.367, $P=0.01$), pulmonary infection (OR 1.203, 95% CI 1.117–1.296, $P<0.001$), SSI (OR 1.323, 95% CI 1.149–1.523, $P<0.001$), ICU admission (OR 1.269, 95% CI 1.158–1.390, $P<0.001$), but not with myocardial infarction, cardiac arrest, sepsis, stroke, 30-day readmission or 30-day reoperation; In multivariable linear regression analysis, at-risk GNRI was independently associated with longer LOS of ICU (OR 1.132, 95% CI 1.049–1.222, $P=0.001$) and longer postoperative LOS (OR 1.677, 95% CI 1.332–2.111, $P<0.001$). (partial factors in Table 4, whole factors in eTables 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10, 12, 13, 14 and 15)

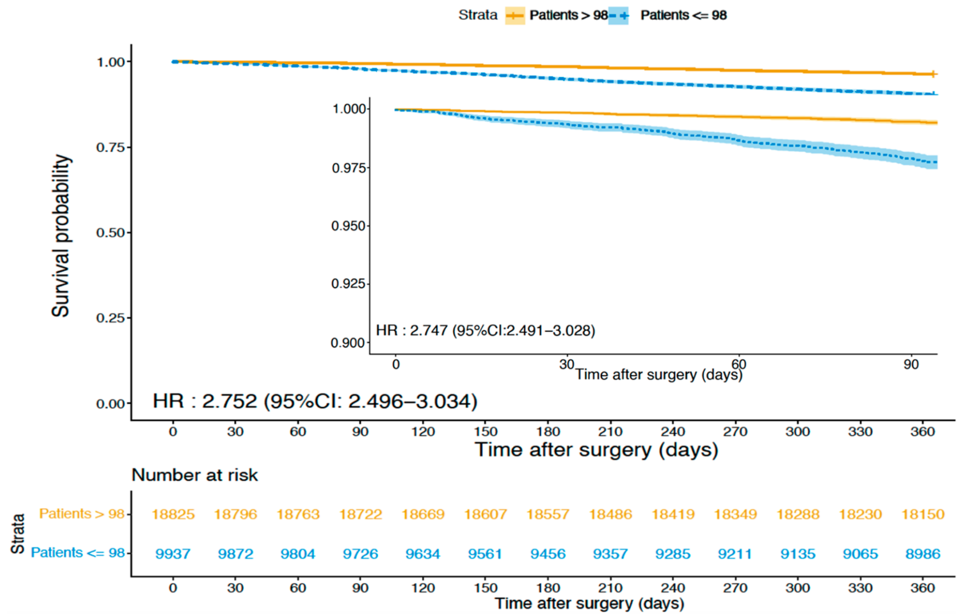
The nonlinear relationship between GNRI and 1-year mortality and postoperative complications

The RCS analysis revealed a nonlinear relationship between GNRI and 1-year all-cause mortality ($P<0.001$; P for nonlinearity = 0.334, Fig. 5): the risk increased substantially with decreasing GNRI below a threshold of 100; at GNRI > 100, the risk remained relatively stable. The inverse relationship between GNRI with postoperative complications was nonlinear for majority of the complications, including heart injury ($P<0.001$; P for nonlinearity = 0.009), arrhythmia ($P<0.001$; P for nonlinearity = 0.048), heart failure ($P<0.001$; P for nonlinearity = 0.407), AKI ($P<0.001$; P for nonlinearity = 0.674), pulmonary infection ($P<0.001$; P for nonlinearity = 0.009), SSI ($P<0.001$; P for nonlinearity < 0.001), ICU admission ($P<0.001$; P for nonlinearity < 0.001), LOS of ICU ($P<0.001$; P for nonlinearity < 0.001), postoperative LOS ($P<0.001$; P for nonlinearity < 0.001), but not myocardial infarction, cardiac arrest, sepsis, stroke, 30-day readmission or 30-day reoperation (eFigure 1). Again, the rate of these postoperative complications increased substantially with decreasing GNRI below a threshold of 100; at GNRI > 100, the risk remained relatively stable.

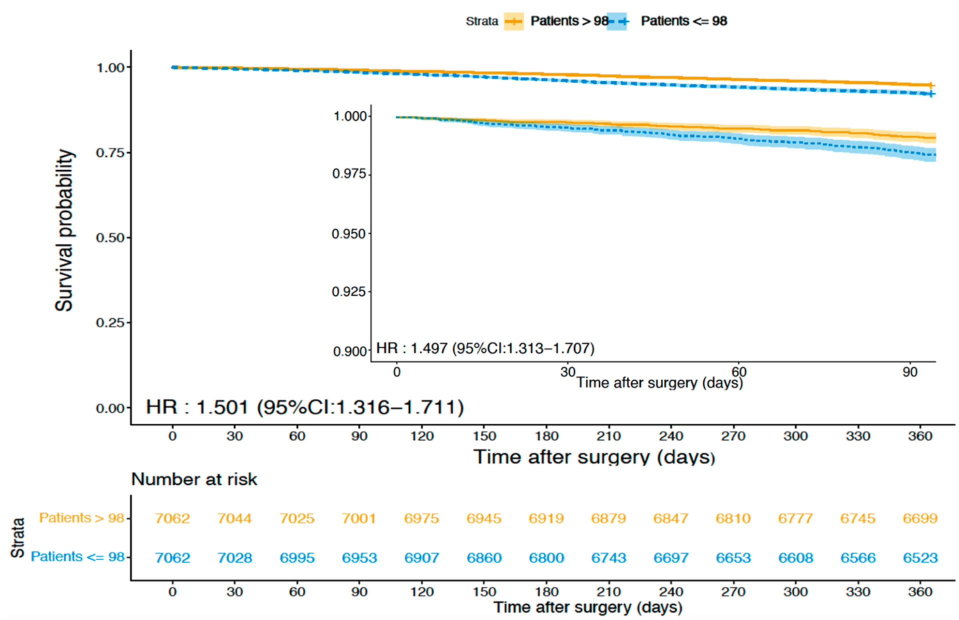
Discussion

In the present study, a retrospective analysis was conducted on the 28,762 patients who underwent non-cardiac surgical treatments in large tertiary hospitals across China. It was demonstrated that patients with at-risk GNRI exhibited a significantly lower one-year OS in comparison to those with no-risk GNRI. At-risk GNRI is associated with a variety of postoperative complications, including postoperative heart injury, acute renal injury, pulmonary infection, surgical site infection, ICU admission, longer ICU LOS, and longer postoperative LOS.

Such a finding is generally consistent with previous studies in elderly patients undergoing specific surgical procedures [18–23]. In a previous study of elderly patients, low preoperative serum albumin and weight loss > 10% in the prior 6 months were associated with poor postoperative outcomes [28]. The nutritional risk



A. Before matching



B. PSM analysis

Fig. 2 Kaplan-Meier survival curves for overall survival. (**A**) Before matching. (**B**) PSM analysis. PSM, propensity score matching

index (NRI), calculated by albumin, PW, and usual body weight (UW), is widely used to evaluate the association between nutrition and postoperative complications [29, 30]. However, the use of NRI in elderly patients is limited since UW is often impossible to obtain in geriatric patients [31]. Instead of UW, GNRI uses IW, which in turn is calculated using the height, and this could be readily used in elderly patients [14].

A number of tools, including prognostic nutritional index (PNI), skeletal muscle mass Index, patient-generated subjective global assessment, malnutrition universal screen tool (Must), and nutritional risk screening 2002 (NRS-2002) are available for assessing nutritional status [32, 33]. All these tools require weight loss in the past 3–6 months, and this are limited for use in daily clinical practice. Subjective global assessment is based on many

Table 2 Cox proportional hazards regression analysis of the association between at-risk GNRI and overall survival

Analysis method	HR	95% CI	*P* value
Cox proportional hazards model regression analysis (*n* = 28,762)			
Model 1 (univariable analysis)	2.752	2.496–3.034	< 0.001
Model 2 (preoperative patient- related covariates adjusted)	1.842	1.647–2.061	< 0.001
Model 3 (surgery-related covariates adjusted)	2.132	1.928–2.359	< 0.001
Model 4 (postoperative patient- related covariates adjusted)	2.468	2.235–2.726	< 0.001
Model 5 (fully adjusted)	1.682	1.502–1.882	< 0.001
Propensity score analysis (multivariable analysis)			
PSM (*n* = 14,126)	1.564	1.372–1.784	< 0.001

HR, hazard ratio; CI, confidence interval; PSM, propensity score matching

Model 1 was a univariate crude model

Model 2 included age, sex, ASA classification, hypertension, diabetes mellitus, coronary heart disease, chronic heart failure, renal dysfunction, malignant tumor, last creatinine level, hemoglobin, platelet, total bilirubin

Model 3 included emergency operation, surgical procedures, duration of procedures, estimated blood loss, blood transfusion, NSAIDS, glucocorticoid, volatile anesthetic, opioid dose, dexmedetomidine

Model 4 included heart injury, AKI, stroke, pulmonary infection, surgical site infection, 30-day readmission, 30-day reoperation, ICU admission, postoperative length of stay

Model 5 included all the confounders

PSM 7063 pairs were matched by propensity score

subjective factors, and expert knowledge is required for clinical implementation [34]. GNRI does not require information of weight loss, and could be readily used in elderly patients in clinical practice.

GNRI categorizes the patients into four risk groups with cutoff values of 82, 92, and 98 [14]. Many studies have been conducted using this classification system and have indicated its prognostic value [35, 36]. In the current study, we used a modified dichotomous classification in an attempt to promote the eventual use in clinical practice. The cutoff value of 98 was based on previous studies [37, 38]. There is no change in reliability by using this modified classification since it maintains the same cutoff originally used by Bouillanne et al. [14]; We combined the original 3 at-risk groups (major, moderate and low) into a single at-risk group (GNRI ≤ 98) and preserved the no-risk group (GNRI > 98). The simplified GNRI classification better promotes its eventual application in clinical practice.

At present, a large number of studies have been conducted on the factors that have an impact on surgical prognosis, such as age, preoperative comorbidities, and surgical modalities. Among these factors, the association between preoperative nutritional status and surgical prognosis has been extensive research in diverse surgical types in recent years. Lower GNRI has been associated with poor short-term outcomes in elderly patients undergoing a variety of procedure, including 30-day mortality in elderly patients undergoing emergency surgery [25], 30-day mortality in patients undergoing surgery for bladder cancer [21], 180-day mortality in patients undergoing hip surgery [39], and 1-year mortality in patients undergoing pancreatomy [40]. The findings in the current study are consistent with these previous studies, this implies that the GNRI possesses predictive value for surgical

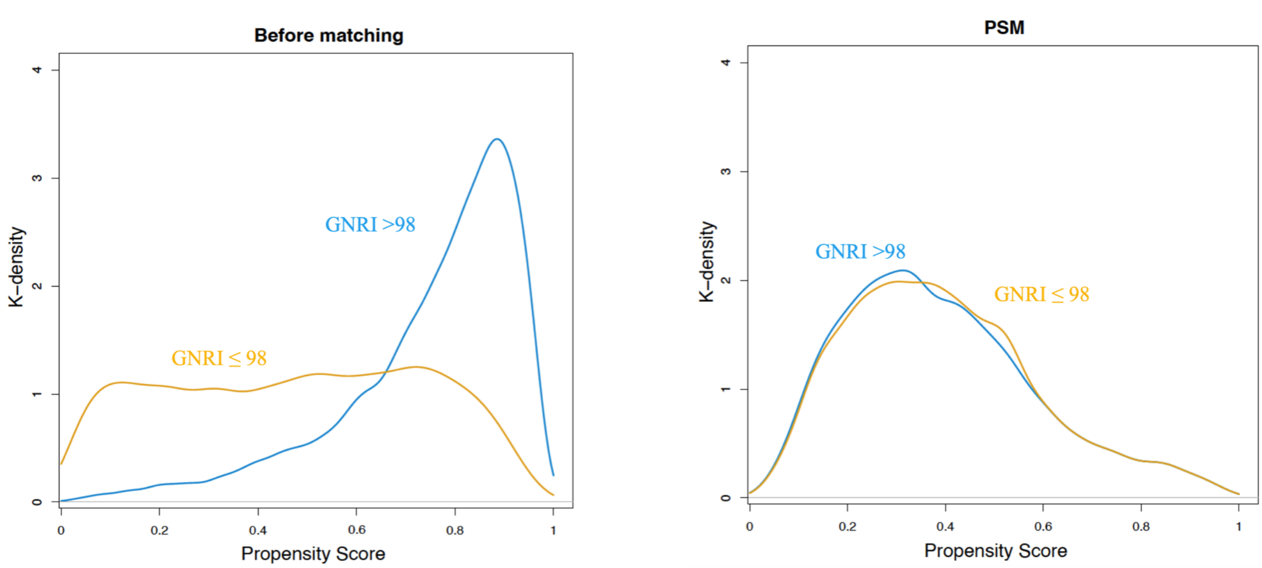


Fig. 3 Distribution of propensity scores in the non-cardiac surgery patients in no-risk group and at-risk group. (**A**) Before matching. (**B**) PSM. PSM, propensity score matching

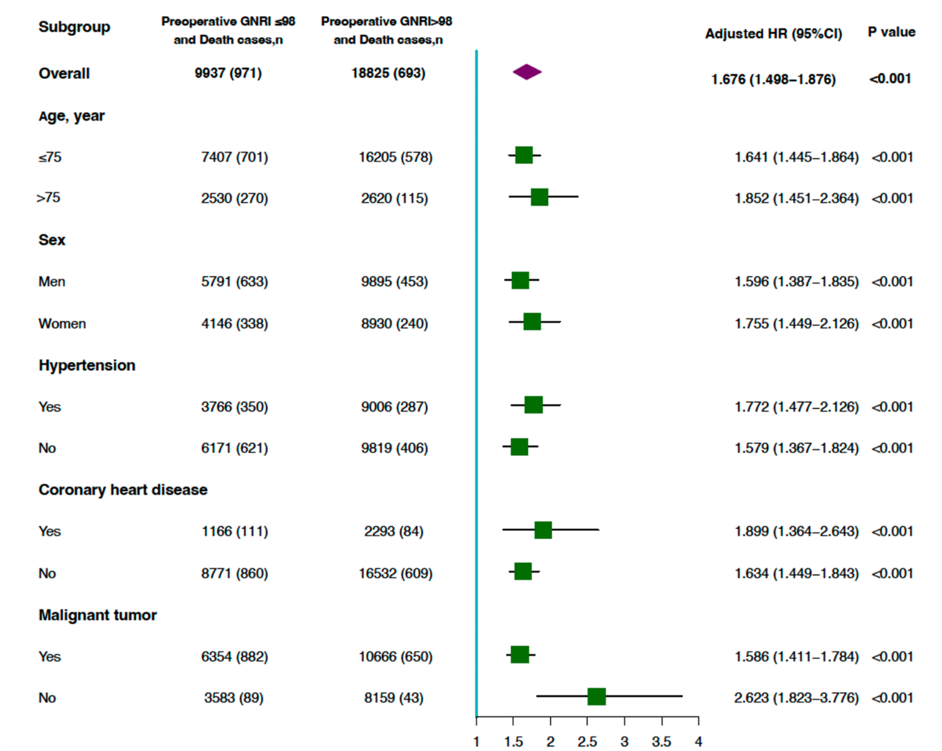


Fig. 4 Subgroup analysis of the association between at-risk GNRI and 1-year overall survival. HR, hazard ratio

Table 3 Association between at-risk GNRI and postoperative complications

	Overall cohort ($N = 28{,}762$)			PSM cohort (1:1) ($N = 14{,}126$)		
Characteristic	**no-risk (18,825)**	**at-risk (9,937)**	***P*-value**	**no-risk (7,063)**	**at-risk (7,063)**	***P*-value**
Heart injury (%)	332 (1.8)	372 (3.7)	< 0.001	149 (2.1)	216 (3.1)	< 0.001
Arrhythmia (%)	223 (1.2)	225 (2.3)	< 0.001	97 (1.4)	138 (2.0)	0.009
Heart failure (%)	44 (0.2)	73 (0.7)	< 0.001	18 (0.3)	41 (0.6)	0.004
Myocardial infarction (%)	40 (0.2)	48 (0.5)	< 0.001	17 (0.2)	27 (0.4)	0.174
Cardiac arrest (%)	25 (0.1)	26 (0.3)	0.02	17 (0.2)	10 (0.1)	0.248
AKI (%)	627 (3.3)	716 (7.2)	< 0.001	323 (4.6)	383 (5.4)	0.023
AKI Stage (%)			< 0.001			0.103
0	18,198 (96.7)	9221 (92.9)		6740 (95.5)	6680 (94.6)	
1	489 (2.6)	570 (5.7)		258 (3.7)	304 (4.3)	
2	61 (0.3)	96 (1.0)		33 (0.5)	46 (0.7)	
3	64 (0.3)	43 (0.4)		29 (0.4)	28 (0.4)	
Pulmonary infection (%)	2500 (13.3)	2150 (21.6)	< 0.001	1157 (16.4)	1324 (18.7)	< 0.001
Surgical site infection (%)	515 (2.7)	565 (5.7)	< 0.001	250 (3.5)	312 (4.4)	0.009
Sepsis (%)	21 (0.1)	52 (0.5)	< 0.001	12 (0.2)	24 (0.3)	0.066
Stroke (%)	112 (0.6)	59 (0.6)	1	39 (0.6)	44 (0.6)	0.66
ICU admission (%)	2198 (11.7)	2151 (21.6)	< 0.001	1039 (14.7)	1235 (17.5)	< 0.001
ICU length of stay (day)	0.00 [0.00, 0.00]	0.00 [0.00, 0.00]	< 0.001	0.48 (2.05)	0.65 (5.03)	0.01
Postoperative length of stay (day)	7.00 [5.00, 10.00]	9.00[6.00, 12.00]	< 0.001	9.43 (10.50)	10.03 (10.15)	0.001
30-day readmission (%)	172 (0.9)	122 (1.2)	0.014	76 (1.1)	81 (1.1)	0.748
30-day reoperation (%)	118 (0.6)	80 (0.8)	0.096	54 (0.8)	53 (0.8)	1
1-year mortality (%)	693 (3.7)	971 (9.8)	< 0.001	374 (5.3)	552 (7.8)	< 0.001

The data are shown as the median [IQR], n (%), or mean (SD)

PSM, propensity score matching; AKI, acute kidney injury; ICU, intensive care unit

Table 4 Multivariable analysis of postoperative complications

Factor	OR	95% CI	*P*-value
Heart injury:			
Age (per year increase)	1.066	1.052–1.081	< 0.001
Coronary heart disease	1.658	1.377–1.989	< 0.001
Malignant tumor	1.570	1.279–1.935	< 0.001
GNRI ≤ 98	1.274	1.089–1.489	0.002
AKI:			
Renal dysfunction	2.637	1.881–3.643	< 0.001
Blood glucose (per mmol/L increase)	1.051	1.021–1.08	< 0.001
Emergency operation	1.627	1.165–2.242	0.004
NSAIDS	1.836	1.537–2.208	< 0.001
GNRI ≤ 98	1.194	1.043–1.367	0.01
Pulmonary infection:			
Current Smoking	1.164	1.051–1.287	0.003
COPD	1.301	1.048–1.604	0.015
Intra-abdominal surgery	2.289	1.761–3.008	< 0.001
Duration of procedures (per min increase)	1.005	1.004–1.005	< 0.001
GNRI ≤ 98	1.203	1.117–1.296	< 0.001
Surgical site infection:			
Blood glucose (per mmol/L increase)	1.052	1.021–1.081	0.001
NSAIDS	1.357	1.149–1.610	< 0.001
GNRI ≤ 98	1.323	1.149–1.523	< 0.001
ICU admission			
Age (per year increase)	1.075	1.066–1.085	< 0.001
ASA III	1.914	1.238–3.046	0.005
Emergency operation	4.382	3.394–5.649	< 0.001
Blood transfusion	1.228	1.076-1.400	0.002
GNRI ≤ 98	1.269	1.158–1.390	< 0.001
ICU length of stay:			
Female sex	1.198	1.110–1.293	< 0.001
Anticoagulants	1.186	1.035–1.358	0.014
GNRI ≤ 98	1.132	1.049–1.222	0.001
Postoperative length of stay:			
Diabetes mellitus	1.654	1.313–2.083	< 0.001
Malignant tumor	4.006	3.061–5.241	< 0.001
Blood transfusion	1.798	1.283–2.519	0.001
Opioid dose (per mg increase)	1.008	1.006–1.011	< 0.001
GNRI ≤ 98	1.677	1.332–2.111	< 0.001

prognosis not only within specific surgical categories but also the population undergoing non-cardiac surgeries. Consequently, it offers theoretical justification for the utilization of GNRI in preoperative evaluation. However, the impact of preoperative GNRI on long-term survival outcomes requires further investigation since previous studies yielded conflicting results. For example, Tamuro et al. [41] reported an independent association between GNRI and 3-year OS in patients undergoing radical resection of colorectal cancer. Moreover, Fang et al. [42] failed to show an association between GNRI and 5-year OS in patients undergoing esophagectomy for esophageal carcinoma.

Furthermore, we noticed that the subgroups still rendered the finding statistically significant with advanced age, sex, hypertension, coronary heart disease, and malignant tumor, which indicated a robustly adverse effect on the overall survival of at-risk GNRI in the elderly non-cardiac patients. Among elderly patients undergoing non-cardiac surgeries, the proportion of patients with malignant tumors was 59.2% in the study. Depending on the cancer diagnosis and stage, malnutrition has been estimated occurring in approximately 30–60% of cancer patients [43]. In this study, the proportion of malignant tumors patients with at-risk GNRI was 63.9%, might due to the research subjects were elderly patients. In the malignant tumor subgroup, the at-risk GNRI was still correlated with the adverse outcomes of patients. There is increasing evidence supporting malnutrition can be associated with improved therapy toxicity, decreased relative-dose intensity, increased treatment delays and dose modifications in malignant tumor patients [44]. Additionally, postoperative adjuvant chemotherapy represents a crucial therapeutic approach for prolonging the survival time of patients with malignant tumors. Kanda et al. [45] discovered that patients with a low PNI prior to surgery did not derive significant advantages from adjuvant chemotherapy. They found that patients with compromised immune and nutritional conditions possess a diminished tolerance to chemotherapy, which gives rise to a reduction in the efficacy of adjuvant chemotherapy, an augmentation in adverse reactions, an acceleration of tumor progression, and consequently, a worsening of the poor prognosis of patients with malignant tumors. Furthermore, anorexia-cachexia syndrome is associated with shortened OS [46]. Therefore, the at-risk GNRI persists

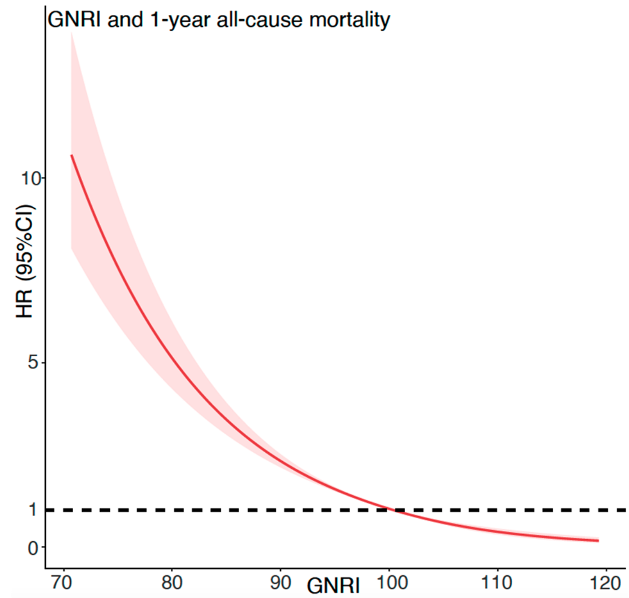


Fig. 5 Restricted cubic spline analysis of the association between GNRI and risk of 1-year all-cause mortality

as a prognostic indicator for the unfavorable prognosis of patients with malignant tumors following non-cardiac surgeries.

Lower GNRI has been associated with a variety of postoperative complications in elderly patients undergoing a variety of surgical procedures, including SSI and pneumonia in patients undergoing curative-intent resection for colorectal cancer [47, 48], postoperative transfusion, readmission and prolonged postoperative LOS in patients undergoing total joint arthroplasty [19], SSI, progressive renal insufficiency, readmission, extended length of stay in patients undergoing nephrectomy for renal cancer [23], blood transfusion, pneumonia, and prolonged LOS in patients undergoing radical cystectomy [21], AKI in elderly patients undergoing cardiac surgery [49], major adverse cardiovascular events in patient undergoing percutaneous coronary intervention [50], and prolonged LOS in patients undergoing non-cardiac surgical patients [51]. The at-risk GNRI group in the current study had higher rate of postoperative complications, including heart injury, AKI, pulmonary infection, SSI, and ICU admission, but not stroke, 30-day readmission, and 30-day reoperation. Multivariate regression analysis indicated that at -risk GNRI was an independent risk factor for heart injury, AKI, pulmonary infection, SSI, ICU admission, LOS of ICU, postoperative LOS. These findings are generally consistent with the past studies.

The strength of the study is that, to the best of our knowledge, this is the first study to investigate the relationship between GNRI and outcomes in elderly noncardiac patients. We assessed the largest cohort in our investigation of the relationship of GNRI and postoperative prognosis and complications in elderly non-cardiac patients. Our study demonstrated that preoperative at-risk GNRI was correlated with increased postoperative complications and worse OS compared with no-risk GNRI and that at-risk GNRI was an independent risk factor for OS, postoperative heart injury, AKI, pulmonary infection, SSI, ICU admission, LOS of ICU, postoperative LOS.

Together with the existing literature, the findings from the current study encourage inclusion of preoperative GNRI assessment in the enhanced recovery after surgery (ERAS) protocol in elderly patients undergoing non-cardiac surgery. However, preoperative nutritional support do not included in ERAS protocols currently [52]. Implementation of GNRI as a biomarker could help to identify malnourished patients at higher risk for postoperative complications, who would benefit from preoperative nutritional optimization.

The current study has several limitations. First, this study was a retrospective study, although we knew that matching according to the Charlson index is better than using the ASA score, due to the missing variables, we still have no way to perform matching based on the Charlson index. Furthermore, retrospective study subject to a variety of biases, such as perioperative nutritional therapy (enteral and parenteral). Second, the definition of elderly patients is changing. While we defined elderly patients as those aged ≥ 65 years in the present study, the life span has extended and the number of patients aged > 75 years or even older has been increasing. Similar analyses may also have to be performed in more elderly patients. Fortunately, we performed a subgroup analysis of > 75 years, and the same conclusions could be drawn. Third, although a PSM analysis were performed, there may be residual confounding from variables not captured in CEPPD. Fourth, the follow-up is relatively short. Whether at-risk GNRI is associated with long-term survival outcomes requires further investigation.

Conclusions

At-risk GNRI was associated with poor survival outcomes and postoperative complications in elderly patients undergoing non-cardiac surgery. We recommend including preoperative GNRI assessment into the ERAS protocol, but prospective studies with longer-term follow-up are warranted.

Abbreviations

AKI	acute renal injury
ASA	American society of anesthesiologists
BMI	body mass index
CI	confidence interval
COPD	chronic obstructive pulmonary disease
CEPPD	Chinese elderly patients' perioperative database
ERAS	Enhanced recovery after surgery
GFR	glomerular filtration rate
GNRI	geriatric nutritional risk index
HR	hazard ratio
ICU	intensive care unit
IQR	interquartile range
IW	ideal weight
LOS	length of stay
MACE	major adverse cardiovascular events
Must	malnutrition universal screen tool
NSAIDS	non-steroid anti-inflammatory drugs
NRS-2002	nutritional risk screening 2002
OR	odds ratio
OS	overall survival
PNI	prognostic nutritional index
PSM	propensity score matching
PW	present weight
SD	standard deviation
SMD	standardized mean difference
SPSS	statistical package for social sciences
SSI	surgical site infection

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-024-05667-x.

Supplementary Material 1

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Author contributions
WDM, JL, and QF designed the research. JBC, HL, JSL, WXZ, JHZ, LYL, LKS, CSZ conducted the research. WXZ, YLM, LBM, XYZ analyzed and interpreted the data. JHZ, JSL, HL, JBC contributed for statistical analysis. WXZ, JHZ and LYL drafted the manuscript. WDM, JL and QF critically revised the manuscript, and had primary responsibility for final content. All authors revised the manuscript and 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 approval and consent to participate
The study was adhered to the Declaration of Helsinki. This study was approved by the Ethics Committee Board of the First Medical Center of Chinese PLA General Hospital (No.S2019-311–03). The need for consent to participate was waived by the Institutional Review Board of the First Medical Center of Chinese PLA General Hospital as the study was retrospective, and all data were anonymized before analysis.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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