https://doi.org/10.1186/s13741-025-00582-0

Perioperative Medicine

RESEARCH

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Geriatric nutritional risk index and prognostic nutritional index improves predictive value of postoperative mortality: a large-scale retrospective cohort study

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Abstract

Background Malnutrition increases the risk of mortality. However, the predictive role of preoperative nutritional status in postoperative mortality remains underexplored. This study investigates the link between preoperative objective nutritional indices and postoperative mortality across all adult surgical patients and evaluates the predictive value of malnutrition for postoperative mortality.

Methods This retrospective study included patients aged 18 or older who underwent surgery. Nutritional status was assessed using the Geriatric Nutritional Risk Index (GNRI) and the Prognostic Nutritional Index (PNI). Logistic regression analysis was performed to explore the relationship between preoperative nutritional status and postoperative mortality and to evaluate the predictive value of nutrition scores for mortality.

Results The study included 79,648 patients. Among them, 12,392 (15.6%) were identified with malnutrition by GNRI, 13,773 (17.3%), by PNI, and 8,633 (10.8%) by both indices. A total of 276 patients died within 30 days after surgery. After adjusting for traditional risk factors, poorer nutritional scores were linked to increased mortality risk. GNRI and PNI also enhanced the predictive accuracy of postoperative mortality models, as evidenced by significant improvements in integrated discrimination and net reclassification.

Conclusions Poor preoperative nutritional status, as indicated by GNRI and PNI scores, is associated with a higher risk of postoperative mortality. Integrating these scores into mortality prediction models significantly enhances their accuracy. These findings highlight the importance of screening surgical patients for malnutrition risk to inform perioperative nutritional management.

Trial registration The Institutional Review Board (IRB) of Seoul National University Hospital No. H-2210–078-1368).

Keywords Postoperative mortality, Geriatric nutritional risk index, Prognostic nutritional index, Prediction model

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Introduction

Preoperative nutritional status can be improved and is a modifiable risk factor affecting surgical outcomes (Prado et al. 2023). Preoperative nutrition status influences a patient's ability to tolerate surgical stress, wound healing rate, length of hospital stays, and overall risk of postoperative complications. Malnutrition affects a significant proportion of surgical patients worldwide. Studies suggest that the prevalence of malnutrition ranges from 20 to 50% in different surgical populations, with notable variations depending on geographic and socioeconomic factors (Bellanti et al. 2022). Cancer-related cachexia and surgical impact on nutritional status can result in significant malnutrition in up to 65% of patients (Martinez-Ortega et al. 2022).

Previous studies have indicated that nutritional status is associated with postoperative mortality, and malnutrition is an independent risk factor for postoperative mortality (Li et al. 2023a; Hou et al. 2023; Ning et al. 2023). Malnourished patients exhibit reduced immunity and a high prevalence of infections (Hu et al. 2019). The hypermetabolic state following surgery elevates nutritional requirements, which exacerbates malnutrition and establishes a vicious cycle. This cycle can ultimately result in severe postoperative complications, including delayed wound healing, cardiovascular events, and sepsis (Li et al. 2023b; Xie et al. 2022).

Preoperative nutritional assessment is a crucial component of perioperative care in surgical departments. Based on these assessments, practices can be implemented to reduce perioperative nutritional deficiencies and prevent muscle mass loss in patients undergoing surgery (Gustafsson et al. 2019; Nematihonar et al. 2018; Franceschilli et al. 2022). The widespread adoption of Enhanced Recovery After Surgery (ERAS) guidelines has heightened awareness of the importance of optimizing nutritional status (Jain et al. 2023; Stenberg et al. 2022). Accurate nutritional assessments underpin effective nutritional management, improving surgical patients'prognosis and significantly reducing postoperative mortality.

Questionnaire-based tools such as Nutritional Risk Screening 2002 (NRS 2002) (Shang et al. 2023), Malnutrition Universal Screening Tool (MUST) (Leonard et al. 2023), Subjective Global Assessment (SGA) (Duerksen et al. 2021), and Mini Nutritional Assessment-short form (MNA-SF) (Kinugasa et al. 2023) are commonly used to assess nutritional status in perioperative patients. However, these indicators do not apply to retrospective studies, where patient recall bias and inadequate descriptions can significantly affect the assessment results. Therefore, screening tools such as the Geriatric Nutritional Risk Index (GNRI) and the Prognostic Nutritional Index (PNI), based on indicators of retrospective laboratory tests, are more suitable for application. GNRI combines serum albumin levels and body mass index (BMI). Although initially developed for geriatric patients, its use has extended to various populations, including surgical, cancer, and chronic disease patients (Hao et al. 2019). PNI combines serum albumin levels with the total lymphocyte count to indicate the patient's nutritional and immune status (Hachisu et al. 2020). Several studies have used GNRI and PNI to investigate the relationship between nutritional status and postoperative mortality (Wang et al. 2023; Tsutsui et al. 2023). However, small sample sizes and specific disease types have led to inconsistent and controversial results. Therefore, studying a large sample size will elucidate the relationship between nutritional status and postoperative mortality across all age groups of surgical patients, making the findings more generalizable.

This retrospective study investigated the relationship between preoperative nutritional status and postoperative mortality in adult patients undergoing surgery. Additionally, we aimed to validate the independent predictive value of GNRI and PNI, as well as whether incorporating nutritional indices along with traditional risk factors would enhance the prediction of postoperative mortality.

Materials and methods

Study population

The data used in this study were sourced from the INSPIRE (INformative Surgical Patient dataset for Innovative Research Environment) database (https://doi.org/10.13026/4evs-wq50), a publicly available research dataset released by Seoul National University Hospital (SNUH) for perioperative medicine. This study was approved by the Institutional Review Board (IRB) of SNUH (No. H-2210–078-1368). The IRB also waived the informed consent due to the retrospective nature of the study design. We conducted this study using this dataset. A waiver of study approval was granted by the IRB of Peking University Third Hospital because of the use of de-identified data. In our study, we included patients aged 18 to 90 who underwent surgical procedures at the SNUH surgical departments from January 2011 to December 2020. For patients undergoing multiple surgeries, this study includes the only information related to the first surgery in the analysis. Patients from non-surgical departments were excluded from the analysis. We also excluded patients with an ASA score of 6 or missing ASA scores and those with missing BMI data, surgical duration data, or preoperative laboratory test results. The final cohort comprised 79,648 patients, including 276 non-survivors 30 days postoperatively.

Assessment of nutritional status

The nutritional status of the enrolled patients was analyzed using the GNRI and the PNI, which effectively assess the nutritional status of surgical patients before surgery (Sun et al. 2024). Indicators were calculated retrospectively using data from the INSPIRE database, with low scores suggesting a higher nutrition risk.

The GNRI is calculated from serum albumin and BMI using the formula: 1.489 × serum albumin (g/L) + [41.7 × weight (kg)/ideal body weight (kg)]. For male patients, ideal body weight was calculated as 0.75 × height (cm) – 62.5; for female patients, it was calculated as 0.60 × height (cm) – 40. GNRI values defined four grades of nutrition-related risk: no nutritional risk (GNRI > 98), mild risk (GNRI 92–98), moderate risk (GNRI 82–91), and severe risk (GNRI < 82) (Bouillanne et al. 2005).

The PNI, based on serum albumin and lymphocyte count, reflects patients'nutritional and immune status. It is calculated using the formula: serum albumin (g/L) + 0.005 × total lymphocyte count ($\times 10^9$/L). Patients were divided into three groups: Normal (PNI > 38), moderate nutritional risk (PNI 35–38), and severe nutritional risk (PNI < 35) (Sun et al. 2024; Buzby et al. 1980).

Data acquisition and outcomes

Patient demographics, laboratory results, operation types, and anesthesia-related variables were extracted from the clinical data warehouse at SNUH (Lim et al. 2024). All data preprocessing and analysis were conducted programmatically using the structured CSV files provided by the INSPIRE dataset. Finally, we selected the following variables: demographics (age, sex, BMI), American Society of Anesthesiologists (ASA) score, emergency surgery status, preoperative laboratory results (serum albumin, lymphocyte count), type of surgery (cardiothoracic, general, neurosurgery, obstetrics and gynecology, otolaryngology, orthopedic, ophthalmology, plastic, and urology), and type of anesthesia (general, monitored anesthesia care, neuraxial, and regional).

The primary outcome of this study is in-hospital mortality within 30 days after surgery. In-hospital mortality data was recorded as binary outcomes, determined by the last recorded mortality date in the electronic medical record within 30 days post-surgery.

Statistical analysis

Continuous variables that were normally distributed were presented as means with standard deviations and compared between groups using the t-test. For continuous variables that were not normally distributed, medians with interquartile ranges (IQRs) were used, and comparisons between groups were made using the Mann–Whitney U test. Categorical variables were reported as counts and percentages, with group comparisons performed using the chi-squared test. Restricted cubic splines were used to visualize the association between continuous nutritional indices and 30-day postoperative mortality.

Univariate and multivariate logistic regression analyses were conducted to investigate the relationship between preoperative nutritional indices and 30-day postoperative mortality, with indices treated as both continuous and ordinal variables. Two multivariate models were developed: Model 1 adjusted for age, sex, body mass index, and American Society of Anesthesiologists physical status, while Model 2 also included emergency surgery status, type of surgery, type of anesthesia, and duration of surgery in addition to the covariates in Model 1. Results are reported as odds ratios (OR) with 95% confidence intervals (CI).

To evaluate the additive predictive value of preoperative nutritional indices for 30-day postoperative mortality, each index was sequentially added to the base models (Model 1 and Model 2) to create updated models. The area under the receiver operating characteristic curve (AUC) was calculated to quantify predictive ability, with changes in AUC assessed using DeLong's method (Momin et al. 2024). The categorical net reclassification index (NRI) and integrated discrimination improvement (IDI) were used to compare the discrimination capacity of the indices for predicting 30-day postoperative mortality.

All analyses were conducted using R version 4.3.3, and a two-sided p-value of < 0.05 was considered statistically significant.

Result

Baseline characteristics

The patient screening process is illustrated in Fig. 1. A total of 99,900 adult patients who underwent surgery were screened. Of these, 19,999 patients lacked the required data, and 253 patients from non-surgical departments were excluded. Finally, 79,648 adult patients were included in the analysis, of whom 79,372 were survivors and 276 were non-survivors. The average age of all patients was 54.9 years. Among these patients, 43.8% were female, 8.6% had an ASA score greater than II, 7.5% underwent emergency surgery, and 81.9% received general anesthesia. The average duration of surgery was 125 min. Compared to survivors, postoperative non-survivors had an older average age (63.9 vs. 54.9 years), a higher percentage of females (60.5% vs. 43.7%), a more significant proportion with ASA scores greater than II (64.2% vs. 8.3%), and a higher rate of emergency surgery

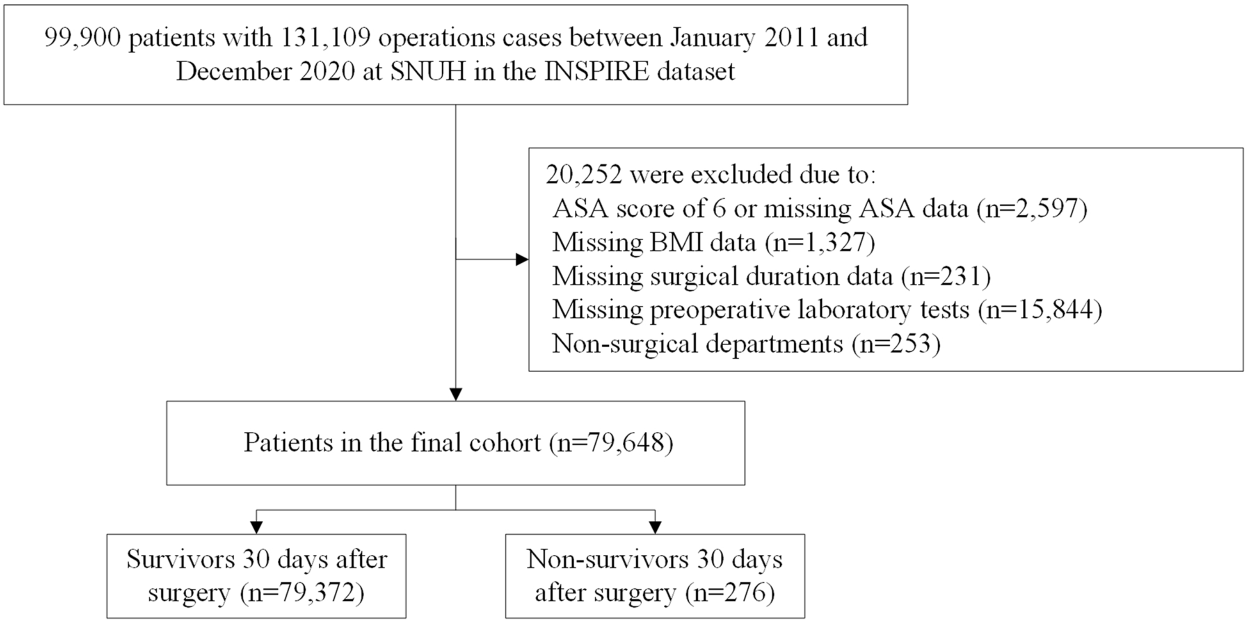

Fig. 1 Flow diagram for patient selection

(47.8% vs 7.3%). The average duration of surgery was significantly longer for non-survivors than for survivors (190 vs 125 min). Additional details on the baseline characteristics of the study are presented in Table 1.

The association between preoperative nutritional status and postoperative mortality

We first analyzed the prevalence of malnutrition. The percentage of patients with malnutrition ranged from 15.6% based on the GNRI to 17.3% based on the PNI score. According to GNRI and PNI calculations, 165 (59.8%) and 219 (79.4%) non-survivors had moderate to severe malnutrition, compared to 4681 (5.9%) and 13,554 (17.1%) survivors (Table 2).

Table 3 shows that both GNRI (OR 0.877, 95% CI 0.868–0.885 for continuous; OR 4.156,95% CI 3.768–4.591 for categorical, separately) and PNI (OR 0.764, 95% CI 0.750–0.778 for continuous; OR 6.686,95% CI 5.766–7.802 for categorical, separately) were significantly associated with postoperative mortality in univariate logistic regression analyses. After multivariable adjustment of the two Models, GNRI and PNI also showed strong associations with mortality. Model 1 was adjusted for age, sex, BMI, and ASA status, while Model 2 included additional adjustments for emergency surgery status, type of surgery, type of anesthesia, and duration of surgery. When GNRI (OR 0.872, 95% CI 0.860–0.884 in Model 1; OR 0.876, 95% CI 0.863–0.889 in Model 2, separately) and PNI (OR 0.815, 95% CI 0.798–0.832 in Model 1; OR 0.820, 95% CI 0.802–0.839 in Model 2, separately) were treated as continuous variables, the results of the restricted cubic splines regression indicated that the OR of postoperative mortality decreased sharply until the GNRI reached approximately 98, after which it remained relatively constant (Fig. 2). Similarly, for PNI, the OR for postoperative mortality exhibited a comparable trend when PNI reached approximately 38 (Fig. 2). We also included GNRI (OR 3.553,95% CI 3.081–4.106in Model 1; OR 3.267, 95% CI 2.811–3.806 in Model 2, separately) and PNI (OR 4.135, 95% CI 3.512–4.891 in Model 1; OR 3.763, 95% CI 3.166–4.493 in Model 2, separately) as categorical grade variables in the logistic model. The results indicated that each additional grade level was associated with an increased risk of postoperative mortality, with the odds of mortality being more than three times higher than the previous nutritional indices grade level (Table 3).

Additive value of nutritional indices in postoperative mortality prediction

We assessed the predictive value of nutritional indices as both continuous and ordinal variables to comprehensively evaluate their effects and ensure robustness of the findings. Continuous variables provide nuanced information on the relationship across a spectrum, while ordinal variables help assess their risk stratification capabilities in discrete categories.

Firstly, we assessed the additional predictive value of nutritional indices when treated as continuous variables. As shown in Table 4, adding GNRI or PNI to both base

Table 1 Baseline characteristics of study participants

	Overall (*N* = 79,648)	Survivors (*n* = 79,372)	Non-survivors (*n* = 276)	*P*
Age, years	54.9 ± 16.1	54.9 ± 16.1	63.9 ± 15.0	< 0.001
Sex, female	34,849 (43.8)	34,682 (43.7)	167 (60.5)	< 0.001
Body-mass index, kg/m^2	23.7 ± 3.5	23.8 ± 3.4	21.9 ± 3.9	< 0.001
ASA				< 0.001
I	29,938 (37.6)	29,915 (37.7)	23 (8.3)	
II	42,865 (53.8)	42,789 (53.9)	76 (27.5)	
III	6420 (8.1)	6292 (7.9)	128 (46.4)	
IV	397 (0.5)	354 (0.4)	43 (15.6)	
V	28 (0.0)	22 (0.0)	6 (2.2)	
Emergency surgery	5937 (7.5)	5805 (7.3)	132 (47.8)	< 0.001
Type of surgery				< 0.001
Cardio-Thoracic Surgery	5990 (7.5)	5922 (7.5)	68 (24.6)	
General Surgery	23,417 (29.4)	23,327 (29.4)	90 (32.6)	
Neurosurgery	6691 (8.4)	6652 (8.4)	39 (14.1)	
Obstetrics & Gynecology	8811 (11.1)	8808 (11.1)	3 (1.1)	
Oto-laryngology	7460 (9.4)	7420 (9.3)	40 (14.5)	
Orthopedic Surgery	11,264 (14.1)	11,239 (14.2)	25 (9.1)	
Ophthalmology	7972 (10.0)	7970 (10.0)	2 (0.7)	
Plastic Surgery	2248 (2.8)	2247 (2.8)	1 (0.4)	
Urology	5795 (7.3)	5787 (7.3)	8 (2.9)	
Type of anesthesia				< 0.001
General	65,200 (81.9)	64,936 (81.8)	264 (95.7)	
MAC	6626 (8.3)	6622 (8.3)	4 (1.4)	
Neuraxial	7734 (9.7)	7727 (9.7)	7 (2.5)	
Regional	88 (0.1)	87 (0.1)	1 (0.4)	
Duration of surgery, min	125.0 (80.0, 210.0)	125.0 (80.0, 205.0)	190.0 (105.0, 361.2)	< 0.001

Data were presented as mean ± standard deviation, median (interquartile range), or number (percentage)

ASA American Society of Anesthesiologists, *MAC* monitored anesthesia care

Table 2 Preoperative laboratory findings and nutritional indices of study participants

	Overall (*N* = 79,648)	Survivors (*n* = 79,372)	Non-survivors (*n* = 276)	*P*
Albumin, g/L	42.0 (40.0, 44.0)	42.0 (40.0, 44.0)	30.0 (25.0, 37.0)	< 0.001
Lymphocyte,/nL	1.86 (1.47, 2.28)	1.86 (1.47, 2.28)	0.81 (0.42, 1.39)	< 0.001
GNRI	108.0 (102.0, 113.0)	108.0 (102.0, 113.0)	87.0 (78.0, 100.0)	< 0.001
Normal (> 98)	67,256 (84.4)	67,181 (84.6)	75 (27.2)	< 0.001
Mild malnutrition (92–98)	7546 (9.5)	7510 (9.5)	36 (13.0)	
Moderate malnutrition (82–91)	3511 (4.4)	3446 (4.3)	65 (23.6)	
Severe malnutrition (< 82)	1335 (1.7)	1235 (1.6)	100 (36.2)	
PNI	42.0 (40.0, 44.0)	42.0 (40.0, 44.0)	30.0 (25.0, 37.0)	< 0.001
Normal (> 38)	65,875 (82.7)	65,818 (82.9)	57 (20.7)	< 0.001
Moderate malnutrition (35–38)	8288 (10.4)	8258 (10.4)	30 (10.9)	
Severe malnutrition (< 35)	5485 (6.9)	5296 (6.7)	189 (68.5)	

Data were presented median (interquartile range) or number (percentage)

GNRI geriatric nutritional risk index, *PNI* prognostic nutritional index

Table 3 Univariable and multivariable analyses of nutritional indices to predict postoperative mortality

	Univariable analysis		Multivariable model1		Multivariable model2	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
GNRI, Per 1-point increment	0.877 (0.868–0.885)	< 0.001	0.872 (0.860–0.884)	< 0.001	0.876 (0.863–0.889)	< 0.001
GNRI, Per 1-grade increment	4.156 (3.768–4.591)	< 0.001	3.553 (3.081–4.106)	< 0.001	3.267 (2.811–3.806)	< 0.001
PNI, Per 1-point increment	0.764 (0.750–0.778)	< 0.001	0.815 (0.798–0.832)	< 0.001	0.820 (0.802–0.839)	< 0.001
PNI, Per 1-grade increment	6.686 (5.766–7.802)	< 0.001	4.135 (3.512–4.891)	< 0.001	3.763 (3.166–4.493)	< 0.001

GNRI geriatric nutritional risk index, *PNI* prognostic nutritional index

Multivariable model 1: adjusting for age, sex, body mass index, American Society of Anesthesiologists physical status

Multivariable model 2: adjusting for variables in model 1 as well as emergency surgery status, type of surgery, type of anesthesia, and duration of surgery

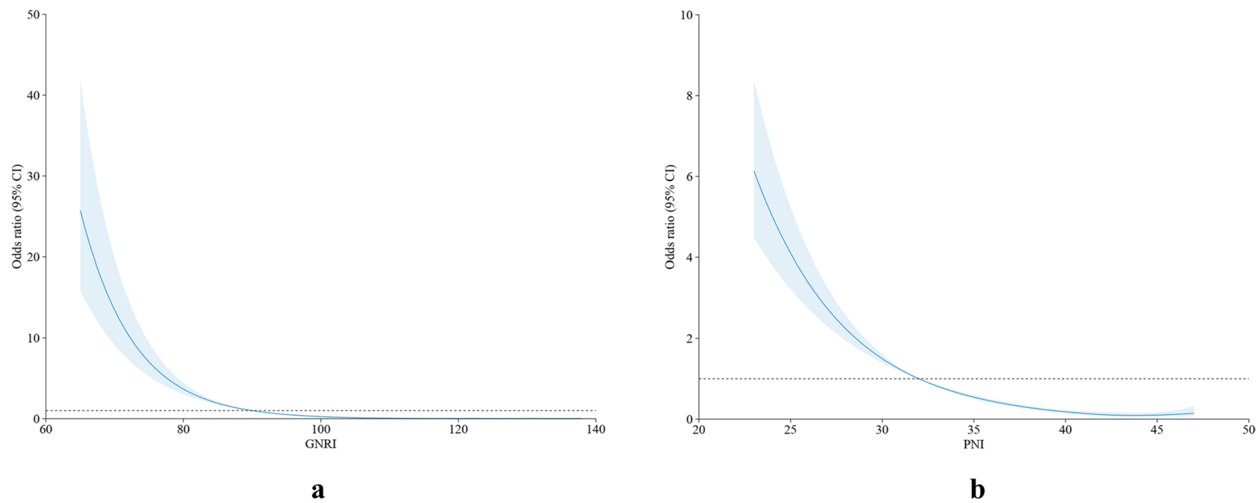

Fig. 2 Restricted cubic spline curves for the relationship between the nutritional scores and postoperative mortality. GNRI, geriatric nutritional risk index; PNI, prognostic nutritional index

models significantly increased the AUC (Model 1: from 0.858 to 0.919 for GNRI and from 0.858 to 0.919 for PNI; Model 2: from 0.909 to 0.944 for GNRI and from 0.909 0.944 for PNI). We found that GNRI and PNI had similar effects on AUC increase and similar NRIs and IDIs (Table 4).

Next, we analyzed GNRI and PNI as ordinal variables. Consistent with their treatment as continuous variables, adding GNRI or PNI to the base models also significantly increased AUC (Model 1: from 0.858 to 0.903 for GNRI and from 0.858 to 0.917 for PNI; Model 2: from 0.909 to 0.935 for GNRI and from 0.909 to 0.942 for PNI). Additionally, we found that GNRI and PNI had similar risk reclassification capabilities when added to the base models (Table 4).

Discussion

In this retrospective cohort study, we analyzed data from 79,648 patients who had undergone surgery to evaluate the predictive capability of malnutrition scores for postoperative mortality. The results indicated that GNRI and PNI were independent predictors of mortality after surgery. We also found that incorporating GNRI or PNI into postoperative mortality prediction models similarly improves predictive ability. When the adjusted variables are removed, GNRI (AUC = 0.860, 95% CI 0.834–0.887 for continuous; AUC = 0.818, 95% CI 0.789–0.847 for categorical, separately) and PNI (AUC = 0.877, 95% CI 0.852–0.903 for continuous; AUC = 0.843, 95% CI 0.817–0.869 for categorical, separately) also demonstrated good discrimination power.

Nutritional status significantly impacts patients undergoing surgical procedures. Nutritional assessment tools used in adult surgical patients include the SGA (Duerksen et al. 2021), MUST (Leonard et al. 2023), NRS-2002 (Shang et al. 2023), MNA-SF (Kinugasa et al. 2023), CONUT (Cheng et al. 2023), GNRI, and PNI. Higher SGA scores are associated with increased mortality rates in gastrointestinal surgery patients (Cho et al. 2022). However, SGA requires a detailed physical examination

Table 4 Performance of models with nutritional indices to predict postoperative mortality

	AUC		Net reclassification improvement		Integrated discrimination improvement	
	AUC (95% CI)	***P***	**Index (95% CI)**	***P***	**Index (95% CI)**	***P***
Nutritional indices as continuous variables						
Base model 1	0.858 (0.833–0.883)					
+ GNRI	0.919 (0.901–0.937)	< 0.001	0.301 (0.237–0.365)	< 0.001	0.037 (0.029–0.046)	< 0.001
+ PNI	0.919 (0.901–0.936)	< 0.001	0.315 (0.252–0.379)	< 0.001	0.038 (0.029–0.046)	< 0.001
Base model 2	0.909 (0.891–0.928)					
+ GNRI	0.944 (0.930–0.957)	< 0.001	0.289 (0.218–0.360)	< 0.001	0.038 (0.029–0.047)	< 0.001
+ PNI	0.944 (0.931–0.957)	< 0.001	0.289 (0.218–0.361)	< 0.001	0.039 (0.029–0.048)	< 0.001
Nutritional indices as ordinal variables						
Base model 1	0.858 (0.833–0.883)					
+ GNRI	0.903 (0.882–0.924)	< 0.001	0.305 (0.242–0.369)	< 0.001	0.031 (0.024–0.039)	< 0.001
+ PNI	0.917 (0.900–0.935)	< 0.001	0.350 (0.287–0.413)	< 0.001	0.022 (0.017–0.027)	< 0.001
Base model 2	0.909 (0.891–0.928)					
+ GNRI	0.935 (0.921–0.950)	< 0.001	0.311 (0.241–0.382)	< 0.001	0.030 (0.022–0.038)	< 0.001
+ PNI	0.942 (0.928–0.955)	< 0.001	0.284 (0.216–0.351)	< 0.001	0.022 (0.016–0.028)	< 0.001

Multivariable model 1: adjusting for ASA, sex, and BMI; Multivariable model 2: adjusting for ASA, sex, BMI, emergency surgery, type of surgery, type of anesthesia, duration of surgery

and comprehensive patient history, which may not fully capture the complexity of nutritional issues in elderly patients, who often have comorbidities and varying frailty (Duerksen et al. 2021). While the effectiveness of NRS-2002 differs significantly depending on the patient population. It is less predictive for patients with gastrointestinal cancers undergoing major abdominal surgery compared to the general surgical population (Wobith et al. 2024). The utility of NRS-2002 lies in its ability to identify and manage nutritional risks early (Hersberger et al. 2020). A score greater than three is associated with worse overall survival rates than lower scores (Li et al. 2019). MUST can screen for nutritional status in all adults, including elderly patients who cannot measure their height and weight (Stratton et al. 2006). However, the effectiveness of MUST in cancer patients is debated. Research suggests that serum albumin levels, which are not directly assessed by MUST, maybe more reliable indicators of protein-energy malnutrition and related postoperative risks (Chao et al. 2015). MNA-SF is a valuable tool for initial nutritional screening, but its predictive accuracy for postoperative outcomes is less robust than other tools (Kokkinakis et al. 2021). CONUT has limitations in assessing postoperative mortality, as optimal cut-off values are not standardized across populations, affecting generalizability (Qian et al. 2021; Sun et al. 2021).

In contrast, GNRI and PNI are cost-effective tools based primarily on objective laboratory measurements. They are easily applied, do not require additional patient participation, and have been widely studied for predicting postoperative complications. GNRI is easy to calculate using albumin levels and weight ratios, making it practical for quick assessments in clinical settings. It is specifically designed for the elderly and is effective in predicting morbidity and mortality in elderly patients with chronic diseases (Lin and Hung 2019). PNI integrates albumin levels and lymphocyte counts, offering a comprehensive view of nutritional status and immune function that applies to various patient populations. PNI may be preferable in resource-limited settings due to lower implementation costs and higher automation potentials. Research has demonstrated that GNRI and PNI are used in various conditions, such as oncology, surgery, chronic diseases, and critical care. Their application now spans various age groups, including younger patients and those with non-malignant conditions, underscoring their critical roles in perioperative nutrition management and outcome improvement (Tsukagoshi et al. 2024; Xie et al. 2020). Our results indicate that adding GNRI or PNI to the prediction model yields similar predictive validity suggesting that GNRI and PNI are equally effective in predicting postoperative mortality in adult surgical patients. Since this study covered a wide age range, we performed a stratified analysis based on age groups (< 65 years and ≥ 65 years) to further evaluate the prognostic value of GNRI and PNI. The analysis revealed that both indices demonstrated good predictive performance for 30-day postoperative mortality in younger and older patient groups (Supplementary1).

Previous studies have emphasized the importance of nutritional status in predicting mortality across various populations and medical conditions. A 10-year cohort study found that GNRI predicts all-cause mortality in elderly patients with acute coronary syndrome (Li et al. 2023a). In a cohort of community-dwelling elderly males, GNRI and MNA-SF were significant predictors of long-term survival. The results indicated that high Charlson Comorbidity Index (CCI) scores and poor nutritional status substantially increased mortality risk (Hou et al. 2023). Nutritional status assessment is predictive not only in older adults but also in populations with comorbidities. A study utilizing data from the National Health and Nutrition Examination Survey (NHANES) found that lower PNI and higher CONUT scores were significantly associated with increased all-cause mortality in patients with type 2 diabetes (Ning et al. 2023). Although malnutrition is strongly linked to postoperative mortality, effective mortality reduction necessitates accurate nutritional assessment and supplementation. Among critically ill patients in the intensive care unit (ICU), early nutritional support was associated with higher 28-day mortality. The results suggested that high levels of early macronutrient provision might be linked to poorer outcomes and highlighted the need for precise nutritional intake assessment (Pardo et al. 2023).

Malnutrition contributes to postoperative mortality through various mechanisms. Malnourished patients exhibit reduced levels of immunoglobulins, lymphocytes, and other immune cells and deficiencies in vitamins and minerals. These factors weaken the immune system, increasing the risk of postoperative infections such as pneumonia, urinary tract infections, and surgical site infections, causing delayed wound healing (Hu et al. 2019). Hypoalbuminemia and electrolyte imbalances are common in malnourished individuals and are associated with fluid shifts, edema, and arrhythmias. These conditions can elevate the risk of cardiac issues (Li et al. 2023b). In addition to cardiovascular effects, weakened gastrointestinal function increases the risk of bacterial translocation from the gut into the bloodstream, decreases nutrient absorption, and potentially leads to sepsis, exacerbating malnutrition. In surgical patients, surgery induces a hypermetabolic state, which increases nutritional requirements and results in a negative nitrogen balance. Moreover, malnutrition causes muscle atrophy, decreasing respiratory muscle strength, and increases the risk of postoperative atelectasis and pneumonia. Muscle weakness can also limit mobility, increasing the risk of deep vein thrombosis and pulmonary embolism (Xie et al. 2022). However, extensive supplementation may not be beneficial. In severely malnourished patients, rapid reintroduction of nutrition could lead to fatal refeeding syndrome. To mitigate these risks, preoperative nutritional assessment is essential. Notably, in oncologic surgical contexts, these malnutrition-related risks are compounded by tumor-specific biological pathways. Malignancy and malnutrition exhibit a bidirectional pathological interplay, this synergistic vicious cycle may significantly elevate mortality risk (Arends 2024; Chauhan et al. 2024).

This study represents the most extensive dataset to date, encompassing all surgical categories and adult age groups. The study results revealed that nutritional status significantly enhances the predictive validity of postoperative mortality in surgical patients. Malnutrition, as defined by GNRI and PNI, is independently associated with postoperative mortality. These metrics can serve as screening tools for assessing mortality risk, enabling the implementation of nutritional interventions to improve survival and prognosis. Implementing a systematic nutritional support program may reduce the total cost of medical institutions by $4.8 million, and medical expenses per patient could potentially save by more than $3800 (Sulo et al. 2017). Nutritional management is critical to ERAS. The ERAS guidelines advocate for routine preoperative nutritional screening to identify patients at risk of malnutrition and to initiate early nutritional interventions (Hubner et al. 2020). Implementing nutrition-focused ERAS protocols, including preoperative carbohydrate loading, immunonutrition, and early postoperative oral feeding by a multidisciplinary team, has been shown to reduce postoperative complications and improve recovery times (Gustafsson et al. 2019; Nematihonar et al. 2018; Franceschilli et al. 2022).

Our study included a large sample of surgical patients. Preoperative screening for mortality risk can guide treatment protocols and improve prognosis, making our results more generalizable. Several limitations of this study should be acknowledged. First, we could not establish a causal relationship between nutritional status and postoperative mortality due to its observational nature. Second, due to the limitations of data accessibility in retrospective studies, the indices used to assess nutritional status were limited, and the lack of nutritional intervention data precluded analysis of treatment effects. Third, the prediction model used only preoperative variables and did not account for the influence of intraoperative factors and postoperative management on mortality. Finally, surgical departments at various medical centers may have variances in managing surgical patients. The results from this single-center retrospective cohort study may limit generalizability. To further validate these findings and enhance the reliability of the conclusions, future prospective studies incorporating key postoperative complications and assessing long-term survival outcomes beyond 30-day mortality are warranted.

Conclusion

In conclusion, our study demonstrated that poor nutritional status, as assessed by GNRI and PNI, is independently associated with an increased risk of postoperative mortality in adult patients after surgery. Incorporating GNRI or PNI scores into the base model for mortality prediction can significantly improve its accuracy. Due to the retrospective nature of the study, we only used indices based on laboratory tests without considering patients' general conditions or comorbidities, limiting the model's comprehensiveness. Further studies are needed to determine if interventions based on these preoperative nutritional assessments could reduce postoperative mortality.

Abbreviations

GNRI	Geriatric Nutritional Risk Index
PNI	Prognostic Nutritional Index
ERAS	Enhanced Recovery After Surgery
NRS 2002	Nutritional Risk Screening 2002
MUST	Malnutrition Universal Screening Tool
SGA	Subjective Global Assessment
MNA-SF	Mini Nutritional Assessment-short form
BMI	Body Mass Index
ASA	American Society of Anesthesiologists score
IQRs	Interquartile Ranges
OR	Odds Ratio
CI	Confidence Interval
AUC	Area under the receiver operating characteristic curve
NRI	Net Reclassification Index
IDI	Integrated Discrimination Improvement
CCI	Charlson Comorbidity Index
NHANES	National Health and Nutrition Examination Survey
ICU	Intensive Care Unit

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13741-025-00582-0.

Supplementary Material 1.

Authors' contributions

Conceptualization, Kaixi Liu and Zhengqian Li; Data curation, Sichen Liu, Qifeng Han and Xiaoxiao Wang; Formal analysis, Sichen Liu and Qifeng Han; Project administration, Yichen Cui; Resources, Xiaoxiao Wang; Investigation, Luhua Chen and Zhuzhu Li; Supervision, Xinning Mi; Methodology, Xiaoxiao Wang; Software, Sichen Liu; Visualization, Yichen Cui; Original draft, Kaixi Liu and Zhengqian Li; Review and editing, Taotao Liu and Xiangyang Guo. Funding acquisition, Xiaoxiao Wang and Zhengqian Li.

Funding

This work was supported by National Natural Science Foundation of China (82101264 and 82271222), Xi'an Jiaotong-Liverpool University, Research Development Fund (RDF-22–02-029), Research Project of Peking University Third Hospital in State Key Laboratory of Vascular Homeostasis and Remodeling (Peking University) (No. 2024-VHR-SY-10).

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board (IRB) of Seoul National University Hospital (SNUH, IRB No. H-2210–078-1368). The IRB also waived the informed consent due to the retrospective nature of the study design.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 14 December 2024 Accepted: 18 August 2025
Published online: 30 September 2025

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