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Article

Preoperative Malnutrition Calculated Using the Geriatric Nutritional Risk Index in Off-Pump Coronary Artery Bypass Grafting

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Abstract

Background: The Geriatric Nutritional Risk Index (GNRI), which assesses nutritional status using the ideal body weight ratio and albumin level, is a useful predictor of long-term cardiovascular disease prognosis. This study aimed to investigate the impact of preoperative GNRI on off-pump coronary artery bypass (OPCAB) surgical outcomes. **Methods**: We analyzed 632 elective OPCAB procedures performed between July 2008 and July 2018. GNRI was calculated as 14.89 × albumin level (g/dL) + 41.7 × (current body weight [kg]/ideal body weight [kg]). Patients were divided into two groups: the low GNRI (≤98, L group, n = 155) and high GNRI (>98, H group, n = 477) groups. We compared perioperative variables and mid-term outcomes, particularly survival rates and freedom from major adverse cardiac or cerebrovascular events (MACCE). **Results**: Patients in the L group were older (72.4 ± 8.6 *vs*. 67.9 ± 10.1 years, $p < 0.001$) and had lower GNRI scores (90.9 ± 5.8 *vs*. 106.0 ± 4.8, $p < 0.001$) than patients in the H group. Perioperative results, including operation time and number of anastomoses, were similar between the groups, with no significant differences in 30-day mortality, perioperative intra-aortic balloon pump use, bleeding, stroke, or mediastinitis rates were observed. However, patients in the L group had a longer postoperative hospital stay than those in the H group (15.4 ± 13.5 *vs*. 12.6 ± 5.8 days, $p = 0.01$). Analyses of long-term outcomes revealed a significant difference in 5-year survival rates (70.9% for the L group *vs*. 83.3% for the H group, $p = 0.002$) but no significant difference in 5-year MACCE rates (84.1% for the L group *vs*. 80.3% for the H group, $p = 0.19$). **Conclusions**: Despite the longer hospital stay for patients in the L group, other perioperative outcomes were similar between the groups, suggesting that a low GNRI should not preclude patients from undergoing OPCAB surgery.

Keywords

coronary artery bypass grafting; malnutrition; Geriatric Nutritional Risk Index

Introduction

Preoperative malnutrition is associated with longer hospital stay and increased morbidity and mortality following cardiac surgery [1,2]. Patients who are malnourished are at a high risk of complications following cardiac surgery, often decreasing the likelihood of regaining independence and necessitating postoperative care. Although coronary artery bypass grafting (CABG) is an appropriate treatment for complicated ischemic heart disease, with favorable postoperative survival rates and freedom from major adverse cardiac or cerebrovascular events (MACCE) [3,4], malnutrition and severe frailty can preclude the possibility of performing CABG. Malnutrition contributes to frailty, underscoring the importance of nutritional assessment in predicting postoperative outcomes. Recent studies have identified various nutritional indicators, such as Controlling Nutritional Status, Prognostic Nutritional Index, Mini Nutritional Assessment-Short Form, and Geriatric Nutritional Risk Index (GNRI), as useful predictors of cardiovascular disease prognosis [1,5–7]. However, some methods are complicated or time-consuming, and there is ongoing debate about the most suitable approach for assessing malnutrition. The GNRI, which is recognized for its simplicity and widespread adoption, was selected for this study. Although comparing the GNRI with other nutritional indicators could highlight its utility, we prioritized conducting the research using an easy-to-measure clinical indicator.

This study aimed to compare the perioperative and mid-term results of patients who underwent off-pump coronary artery bypass (OPCAB), stratified into two groups based on GNRI points, particularly focusing on survival and freedom-from-MACCE rates.

Materials and Methods

Data Source

This study included 632 patients treated at Toyohashi Heart Center between 2008 and 2018. Among the various nutritional indices, the GNRI was chosen for its simplicity in calculation. GNRI was determined using the formula:

14.89 × albumin level (g/dL) + 41.7 × (current body weight [kg]/ideal body weight [kg]). Patients were categorized into two groups based on their GNRI points: those with scores ≤98 into the L group and those with scores ≥98 into the H group [8]. The medical records of all patients were retrospectively reviewed (Fig. 1). Patient confidentiality was ensured throughout the study, following the principles of the Declaration of Helsinki. The study protocol was approved by the Ethics Committee of Toyohashi Heart Center, Aichi Prefecture (approval number: 220310), and written informed consent was obtained from all the participants.

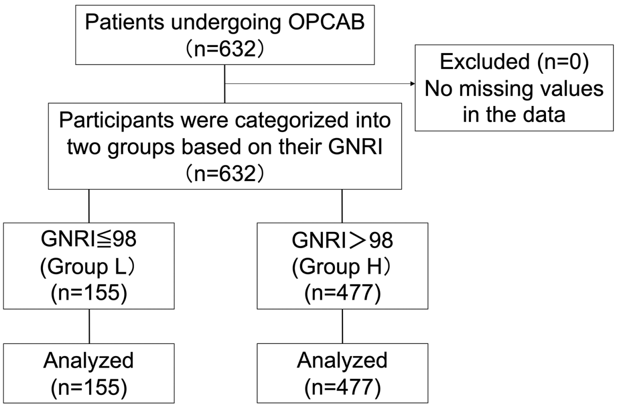

Fig. 1. Patient flow diagram. OPCAB, off-pump coronary artery bypass; GNRI, Geriatric Nutritional Risk Index.

Study Variables

The study population included 155 patients in the L group and 477 patients in the H group. We evaluated the preoperative characteristics, conditions, operative findings, and mid-term results of both groups. The periods of all-cause mortality and MACCE were analyzed.

Statistical Analyses

Univariate comparisons of patient characteristics and operative outcomes are presented as counts and percentages for categorical variables and as mean ± standard deviation for continuous variables. Categorical variables were analyzed using Fisher's exact two-tailed test.

The observation period continued until the patient's last recorded survival date. MACCE and survival rates were calculated using Kaplan–Meier estimates, with differences between the two groups evaluated using log-rank tests.

Univariate and multivariate Cox regression analyses were used to examine the association between all-cause mortality and MACCE. Variables with a *p*-value < 0.05 in the univariate analysis were included in the multivariate model. A *p*-value < 0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22 (IBM Corp., Armonk, NY, USA).

Results

The 632 patients included in this study were categorized based on their GNRI scores (Table 1). Significant differences were observed between the two groups (L *vs.* H group) in terms of age (72.4 ± 8.6 *vs.* 67.9 ± 10.1 years, respectively; $p < 0.001$), serum albumin level (3.8 ± 0.4 *vs.* 4.1 ± 0.5, respectively; $p = 0.005$), and GNRI scores (90.9 ± 5.8 *vs.* 106.0 ± 4.8, respectively; $p < 0.001$). No significant differences in sex, height, body weight, body mass index, serum creatinine, hematocrit, total lymphocyte count, diabetes, hemodialysis, hypertension, or left ventricular ejection fraction were observed between the groups at baseline.

Table 2 presents the operative data and early results. No significant differences were observed between the groups in terms of operation time, use of a postoperative intra-aortic balloon pump, reoperation for bleeding, postoperative stroke, and mediastinitis. Mortality rates were 0.6% and 0.2% in the L and H groups, respectively. The length of hospital stay was 15.4 ± 13.5 days and 12.6 ± 5.8 days for the L and H groups ($p = 0.034$). The number of anastomoses was 3.1 ± 0.9 and 3.3 ± 1.0 in the L and H groups, respectively ($p = 0.120$).

Table 3 presents the findings pertaining to the univariate and multivariate analyses associated with all-cause mortality. In the univariate analysis, all-cause mortality was significantly associated with age, body mass index, hemodialysis, serum albumin, serum creatinine, and GNRI. In the multivariate analysis, age (hazard ratio [HR]: 1.08, 95% confidence interval [CI]: 1.05–1.12), serum albumin (HR: 0.18, 95% CI: 0.08–0.38), serum creatinine (HR: 1.14, 95% CI: 1.07–1.21), and GNRI (HR: 0.91, 95% CI: 0.83–0.99) were predictors of all-cause mortality.

Table 4 summarizes the findings pertaining to the univariate and multivariate analyses associated with MACCE. In the univariate analysis, MACCE was significantly associated with ejection fraction. In the multivariate analysis, after controlling for confounders like age and sex, ejection fraction (HR: 0.88, 95% CI: 0.87–0.95) was an independent predictor of MACCE after OPCAB.

Fig. 2A,B show Kaplan–Meier curves for freedom from all-cause mortality and MACCE, respectively. The freedom from all-cause mortality at 1, 3, and 5 years was 92.8%, 82.5%, and 70.9%, respectively, in the L group and 97.1%, 91.4%, and 83.3%, respectively, in the H group, with significant differences observed between the groups ($p = 0.002$). The freedom from MACCE at 1, 3, and 5 years was 97.1%, 87.8%, and 84.1%, respectively, in the L group and 94.2%, 87.4%, and 80.3%, respectively, in the H group,

Table 1. Preoperative differences in patient characteristics.

Characteristic	Group L (n = 155)	Group H (n = 477)	p-value
Age, years	72.4 ± 8.6	67.9 ± 10.1	0.001
Male sex (%)	77.1	80.3	0.341
Height (cm)	159.4 ± 10.4	160.6 ± 6.1	0.481
Body weight (kg)	62.1 ± 12.2	66.3 ± 8.4	0.618
Body mass index (kg/m^2)	24.4 ± 3.1	25.7 ± 3.0	0.180
Diabetes (%)	50.7	46.9	0.328
Hypertension (%)	28.5	25.7	0.379
Hemodialysis (%)	11.4	9.6	0.465
Serum albumin (g/dL)	3.8 ± 0.4	4.1 ± 0.5	0.050
Serum creatinine (mg/dL)	1.84 ± 2.1	1.78 ± 2.9	0.940
Hematocrit (%)	36.6 ± 4.7	37.4 ± 5.7	0.260
Total lymphocyte count (10^3/µL)	1.3 ± 0.6	1.31 ± 0.7	0.510
GNRI	90.9 ± 5.8	106.0 ± 4.8	<0.001
Ejection fraction (%)	52.5 ± 14.0	56.2 ± 12.0	0.310

GNRI, Geriatric Nutritional Risk Index. Patients were categorized into two groups based on their GNRI points: an L group (those with points ≤98) and an H group (those with points ≥98).

Table 2. Intraoperative and postoperative differences in patient characteristics.

	Group L (n = 155)	Group H (n = 477)	p-value
Operation time (min)	245.9 ± 63.8	254.7 ± 53.3	0.140
Number of distal anastomoses	3.1 ± 0.9	3.3 ± 1.0	0.120
Use of IABP (%)	2.6	2.2	0.080
Reoperation for bleeding (%)	1.9	0.6	0.150
Stroke (%)	2.5	1.0	0.160
Mediastinitis (%)	1.5	1.2	0.910
Hospital stay (days)	15.4 ± 13.5	12.6 ± 5.8	0.034
30-day mortality (%)	0.6	0.2	0.900

IABP, intra-aortic balloon pump. Patients were categorized into two groups based on their GNRI points: an L group (those with points ≤98) and an H group (those with points ≥98).

with no significant difference observed between the groups (p = 0.19).

Table 5 presents data on all-cause mortality after OPCAB. Patients in the H group were significantly less likely to die of pneumonia than those in the L group. No other statistically significant differences in all-cause mortality were observed between the groups.

Discussion

Malnutrition is an indicator of prolonged hospital stay and a predictor of postoperative outcomes following cardiac surgery [1,9]. In this study, patients in the low GNRI group had longer hospital stay, but no significant differences were observed in other perioperative outcomes. This contrasts with the results of previous studies, which were potentially influenced by the absence of cardiopulmonary bypass (CPB). Unosawa *et al.* [1] highlighted the importance of preoperative nutritional status assessment using the GNRI in predicting the risk of postoperative complications following cardiac surgery. Cardiac surgery involving CPB triggers an acute-phase reaction that is implicated in the pathogenesis of various postoperative complications. CPB is a primary factor in stroke occurrence during cardiac surgery [10]. However, the advent of OPCAB has enabled direct comparisons of stroke risk with and without CPB, revealing no significant differences [11]. OPCAB offers several potential benefits, including reduced cognitive impairment post-surgery, lower incidence of renal failure, decreased blood loss, shorter mechanical ventilation durations, reduced intensive care unit and hospital stay, and lower mortality rates in high-risk patients [12–16]. Beckermann *et al.* [17] reported OPCAB's utility for patients undergoing dialysis, addressing concerns related to body fluid balance and inflammatory cytokine production associated with extracorporeal circulation. With approximately 10% of our study cohort on dialysis, OPCAB may be particularly beneficial in Japan, where the prevalence of dialysis is high. Initially, primary cardiac death was a common

Table 3. Cox regression analyses for the prediction of all-cause mortality.

	Univariate analysis		Multivariate analysis	
	HR (95% CI)	*p*-value	HR (95% CI)	*p*-value
Age, years	1.08 (1.05–1.11)	0.002	1.08 (1.05–1.12)	0.001
Male sex (%)	0.63 (0.36–1.11)	0.110		
Body mass index (kg/m^2)	0.90 (0.84–0.96)	0.001	0.99 (0.96–1.04)	0.877
Diabetes (%)	1.00 (0.64–1.54)	0.980		
Hypertension (%)	0.68 (0.42–1.11)	0.120		
Hemodialysis (%)	3.53 (2.19–5.69)	0.001	1.15 (0.56–2.39)	0.702
Serum albumin (g/dL)	0.41 (0.29–0.59)	0.001	0.18 (0.08–0.38)	0.001
Serum creatinine (mg/dL)	1.13 (1.07–1.19)	0.001	1.14 (1.07–1.21)	0.001
Hematocrit (%)	0.95 (0.86–1.18)	0.220		
Total lymphocyte count (10^3/µL)	1.00 (0.99–1.00)	0.566		
GNRI	0.52 (0.34–0.79)	0.001	0.91 (0.83–0.99)	0.038
Ejection fraction (%)	1.25 (0.91–1.66)	0.210		

GNRI, Geriatric Nutritional Risk Index; HR, hazard ratio; CI, confidence interval. Patients were categorized into two groups based on their GNRI points: an L group (those with points $\leq$98) and an H group (those with points $\geq$98).

Table 4. Cox regression analysis for the prediction of major adverse cardiac or cerebrovascular events.

	Univariate analyses		Multivariate analyses	
	HR (95% CI)	*p*-value	HR (95% CI)	*p*-value
Age, years	0.99 (0.97–1.01)	0.519		
Male sex (%)	0.83 (0.50–1.36)	0.460		
Body mass index (kg/m^2)	0.97 (0.91–1.03)	0.279		
Diabetes (%)	0.82 (0.52–1.27)	0.817		
Hypertension (%)	1.30 (0.75–2.25)	0.352		
Hemodialysis (%)	1.39 (0.77–2.52)	0.277		
Serum albumin (g/dL)	1.39 (0.93–2.08)	0.109		
Serum creatinine (mg/dL)	1.04 (0.96–1.12)	0.362		
Hematocrit (%)	0.98 (0.94–1.02)	0.237		
Total lymphocyte count (10^3/µL)	1.00 (0.99–1.00)	0.294		
GNRI	1.44 (0.83–2.50)	0.195		
Ejection fraction (%)	0.88 (0.80–0.97)	0.012	0.87 (0.84–0.95)	0.006

GNRI, Geriatric Nutritional Risk Index; HR, hazard ratio; CI, confidence interval. Patients were categorized into two groups based on their GNRI points: an L group (those with points $\leq$98) and an H group (those with points $\geq$98).

complication in the early years of CABG procedures [10]; however, OPCAB is tolerable even in patients with preoperative malnutrition.

Sarcopenia, characterized by decreased muscle mass and function, has recently gained attention owing to its implications for perioperative outcomes and postoperative complications; moreover, studies have investigated its association with CABG [18,19]. However, diagnosing sarcopenia by using computed tomography to measure the skeletal muscle index is complicated.

Although no significant difference in freedom from MACCE was observed between the two groups, a notable disparity was observed in the 5-year survival rate, particularly among older patients in the low and high GNRI groups. The low GNRI group, with more older adults, may also have been at an increased risk for pneumonia and cancer. The multivariate analysis revealed that age, serum albumin, serum creatinine, and GNRI were significant prognostic factors for all-cause mortality. Diseases such as chronic renal failure and cirrhosis, which affect albumin production, contribute to malnutrition. Both GNRI and markers of malnutrition, such as serum creatinine and serum albumin, are prognostic factors for all-cause mortality. Based on our findings, cancer was the most common cause of death in both groups, followed by pneumonia, which was more prevalent in the low GNRI group. Malnutrition is a significant risk factor for pneumonia. Whether or not nutrition is addressed, OPCAB for coronary revascularization may not influence the occurrence of major cardiovascular events in patients requiring the procedure. Our

Table 5. Causes of death during follow-up.

Cause of death	Group L (n = 155)	Group H (n = 477)	*p*-value
Cardiac	7 (4.5)	15 (3.1)	0.450
Pneumonia	7 (4.5)	7 (1.5)	0.030
Gastrointestinal hemorrhage	1 (0.6)	4 (0.8)	0.642
Renal failure	2 (1.3)	2 (0.4)	0.253
Sepsis	2 (1.3)	2 (0.4)	0.253
Cerebrovascular disorder	4 (2.6)	13 (2.7)	0.592
Cancer	8 (5.2)	26 (5.5)	0.539
Liver cirrhosis	1 (0.6)	1 (0.2)	0.431

GNRI, Geriatric Nutritional Risk Index. Patients were categorized into two groups based on their GNRI points: an L group (those with points $\leq$98) and an H group (those with points $\geq$98). Data are presented as n (%) of patients.

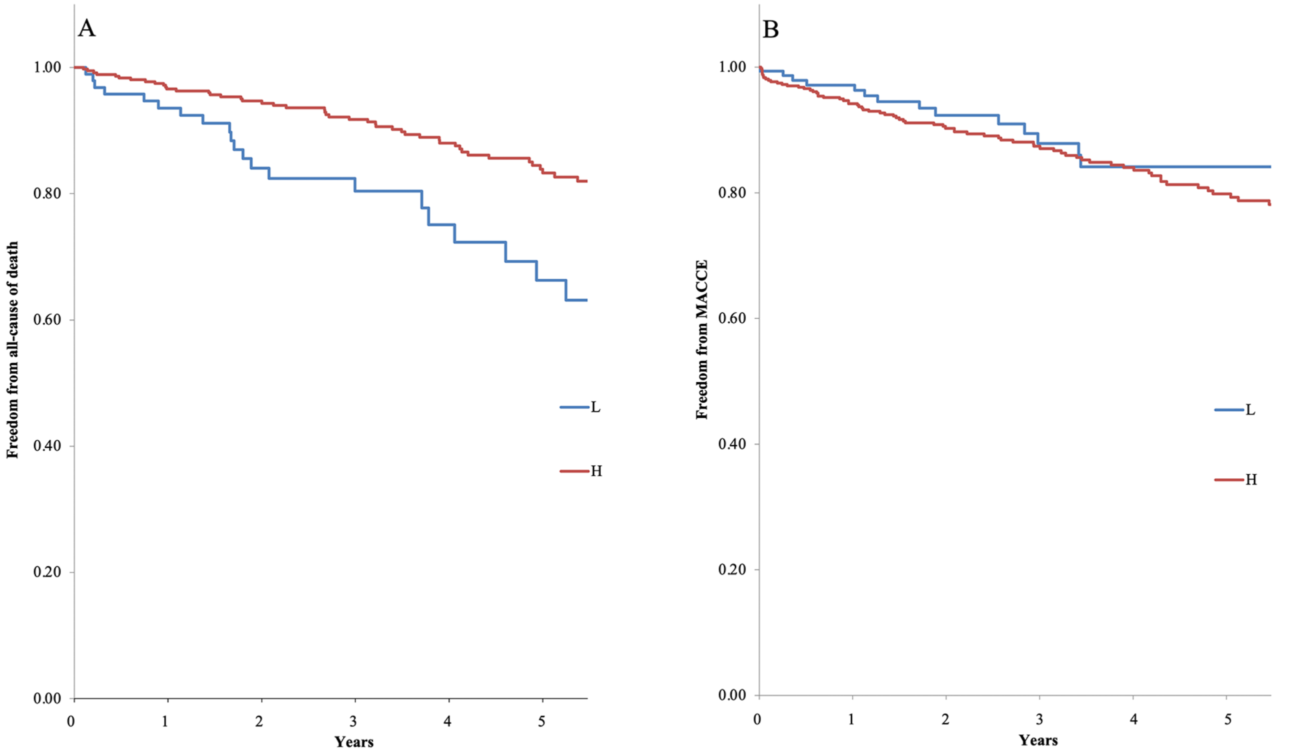

Fig. 2. Kaplan–Meier curves after OPCAB. (A) Freedom from all-cause mortality and (B) freedom from MACCE. OPCAB, off-pump coronary artery bypass; MACCE, major adverse cardiac or cerebrovascular events.

findings indicate that only preoperative ejection fraction influenced MACCE. Therefore, in the context of OPCAB, a low GNRI did not correlate with postoperative complications or MACCE rates.

Our findings suggest that while malnutrition does not impact perioperative outcomes and freedom from MACCE in patients undergoing OPCAB, the long-term survival rates are notably lower. Thus, follow-up on post-OPCAB nutritional status is crucial.

The study's findings also suggest that in regions with high rates of malnutrition or where malnutrition disproportionately affects certain demographic groups, such as older populations or individuals with chronic illnesses, nutritional assessments and interventions are crucial for patients undergoing cardiac surgery. Healthcare providers in these regions should prioritize preoperative nutritional screening and postoperative nutritional support to improve long-term survival outcomes after OPCAB.

The limitations of this study include its retrospective design and sole reliance on GNRI to assess malnutrition. A selection bias may have arisen from the non-randomized selection of patients, potentially skewing the study population towards certain demographics or characteristics. For instance, patients with more severe malnutrition or a higher surgical risk may have been more likely to undergo OPCAB, potentially affecting the study's findings. Additionally, excluding certain patients from the analysis, such as those with incomplete medical records or missing data on key variables, could have introduced a selection bias. Information bias due to inaccuracies or inconsistencies in the documentation and retrieval of data from the medical records may have been present. Retrospective studies rely heavily on existing records, which may vary in completeness and quality. Inaccuracies in recording variables, such as GNRI scores, comorbidities, and postoperative complications, could have introduced bias into the analysis and affected the study results. To our knowledge, this is the first longitudinal observational study that compared OPCAB outcomes with GNRI scores.

Conclusions

Patients in the low GNRI group and those in the high GHRI group had comparable perioperative outcomes and MACCE rates following OPCAB surgeries. However, a significant between-group difference was noted in the 5-year survival rates. Our findings suggest that OPCAB may be suitable for patients with a low GNRI, indicating its applicability across a broader patient population. Longitudinal and multicenter studies are essential to validate the study's findings and enhance the reliability of the GNRI as a predictive tool in OPCAB surgeries.

Availability of Data and Materials

The datasets generated or analyzed during the current study are included in this published article.

Author Contributions

ST and YaO contributed to the design of this work. ST, YuO, and JY contributed to the interpretation of data. ST and YG analyzed the data. ST drafted the work and revised the work critically for important intellectual content. All authors contributed to editorial changes in the manuscript. All authors have read and approved the final manuscript. All authors agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics Approval and Consent to Participate

Patient confidentiality was ensured throughout the study, following the principles of the Declaration of Helsinki. The study protocol was approved by the Ethics Committee of Toyohashi Heart Center, Aichi Prefecture (approval number 220310), and written informed consent was obtained from all participants.

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Conflict of Interest

The authors declare no conflict of interest.

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