Original Article

Nutritional indices for screening sarcopenia before adult cardiac surgery

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Background: Malnutrition can increase and exacerbate sarcopenia, and preoperative nutritional indices could have potential use as screening tools for sarcopenia in all patients, not only those with limited activity. Muscle strengths, such as grip strength, chair stand test, are used to screen for sarcopenia, but these measurements are time-consuming and cannot be applied to all patients. This retrospective study was conducted to determine whether nutritional indices can predict the presence of sarcopenia before adult cardiac surgery.

Methods: The study subjects were 499 patients aged ≥18 who had undergone cardiac surgery using a cardiopulmonary bypass (CPB). Bilateral psoas muscle mass areas at the top level of the iliac crest were measured by abdominal computed tomography. Preoperative nutritional statuses were evaluated using COntrolling NUTritional status (CONUT) score, Prognostic Nutritional Index (PNI), and Nutritional Risk Index (NRI). Receiver operating characteristic (ROC) curve analysis was used to identify the nutritional index that best predicted the presence of sarcopenia.

Results: The 124 patients (24.8%) in the sarcopenic group were older (69.0 *vs.* 62.0 years; P<0.001), and had a lower mean body weight (58.90 *vs.* 65.70 kg; P<0.001) and body mass index (BMI) (2.22 *vs.* 2.49 kg/m^2; P<0.001), and a poorer nutritional status than the 375 patients in the non-sarcopenic group. ROC curve analysis showed that NRI [area under the curve (AUC) 0.716, confidence intervals (CI): 0.664–0.768] better predicted the presence of sarcopenia than CONUT score (AUC 0.607, CI: 0.549–0.665) or PNI (AUC 0.574, CI: 0.515–0.633). The optimal NRI cut-off value was 105.25, which provided a sensitivity of 67.7% and a specificity of 65.1% for the prevalence of sarcopenia. The median durations of mechanical support (17 *vs.* 16 hours; P=0.008) and intensive care unit stay (3 *vs.* 2 days; P=0.001) were significantly longer in the sarcopenic group.

Conclusions: NRI offers a more straightforward, faster, and reproducible screening tool than muscle strength or mass measurement for identifying sarcopenia, and an alternative means of assessment in patients with limited activity before adult cardiac surgery.

Keywords: Cardiac surgery; postoperative complications; sarcopenia; nutritional indices; screening

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Introduction

Sarcopenia was recently recognized to be strongly related to outcomes after cardiac surgery (1-3), and as cardiac surgery is becoming more common in the elderly population, the prognostic relevance of sarcopenia has become a topic of interest. Methods used for screening sarcopenia involve measuring muscle strengths, such as grip strength, chair stand test (4), and various confirmatory muscle mass-associated methods are available, such as impedancemetry, magnetic resonance imaging (MRI), computed tomography (CT), dual X-ray absorptiometry (DEXA), and sonography (3,4). However, these modalities incur time and cost penalties. Another tool is required to screen the presence of sarcopenia in patients with acute heart failure or with care in the intensive care unit (ICU), who can not measure muscle strength.

Malnutrition can exacerbate sarcopenia and is a well-known risk factor of poor outcomes after adult cardiac surgery (5) and nutritional indices have been developed to assess preoperative nutritional status (6-9). The Controlling Nutritional Status (CONUT) score, Prognostic Nutritional Index (PNI), and Nutritional Risk Index (NRI) are commonly used as objective indices, which have the merit of enabling the assessment of nutritional status using simple, reproducible variables, such as serum albumin and total cholesterol levels, total lymphocyte counts, and body weights (6-9).

We considered that if a relation exists between nutritional indices and sarcopenia, these indices might be used to screen the presence of sarcopenia. Thus, we investigated the possibility of nutritional indices to predict the presence of sarcopenia before adult cardiac surgery. Additionally, we investigated to examine whether clinical outcomes might be better predicted when nutritional indices and the presence of sarcopenia are identified together. We present this article in accordance with the STARD reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-22-1865/rc).

Highlight box

Key findings

- Nutritional risk index may be an alternative assessment tool to screen for sarcopenia prior to adult cardiac surgery.

What is known and what is new?

- Sarcopenia is associated with a longer duration of mechanical ventilator support and intensive care unit stay after adult cardiac surgery. Nutritional risk index has the potential to screen for sarcopenia, and the advantage, which is to enable simpler, faster, and easier screening than existing methods. Nutritional risk index has also useful for especially patients with restricted activity.
- The coexistence of sarcopenia and malnutrition before cardiac surgery could increase the duration of intensive care unit and ventilator support.

What is the implication, and what should change now?

- Screening patients with the nutritional risk index may allow identifying sarcopenic patients at special risk for adverse postoperative outcomes, with the possibility of preoperative nutrition intervention.

Methods

Patients and study design

Between January 2013 and December 2019, 655 patients aged >18 underwent cardiac surgery using cardiopulmonary bypass (CPB) at our institute. After excluding patients without preoperative abdominal CT images or a serum cholesterol level, 499 patients were enrolled in the study. Data were retrospectively collected by reviewing the electronic database of our institutional medical record system. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Gil Medical Center (No. GDIRB2022-055), and individual consent for this retrospective analysis was waived.

Patients were allocated to sarcopenic (n=124) or non-sarcopenic (n=375) groups using bilateral psoas muscle areas index. Bilateral psoas muscle areas were measured at the top level of the iliac crest by preoperative CT performed within 1 month of surgery, and psoas muscle mass index was calculated by summing bilateral areas (cm^2) and dividing by height squared (m^2). Areas were manually measured by outlining bilateral psoas muscle borders through an INFINITT PACS® (INFINITT Healthcare, Seoul, Korea) using a computer (*Figure 1*). Sarcopenia in this study was defined as a psoas muscle index in the lowest sex-specific quartile by referring to the literatures because no international cut-off value of psoas muscle mass index was available for sarcopenia (1,10-12).

Preoperative nutritional statuses were evaluated using CONUT score, PNI, and NRI. CONUT score was calculated using the CONUT scoring system (Table S1), which is based on serum albumin, total cholesterol, and total lymphocyte count (13,14). Patients were also grouped

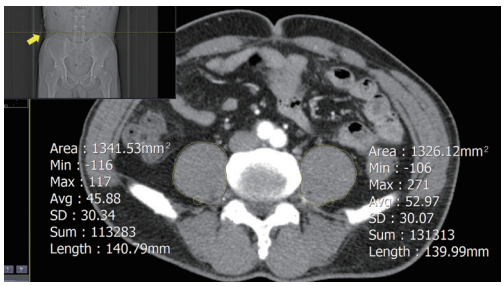


Figure 1 Measurement of bilateral psoas muscle area by preoperative abdominal computed tomography. Psoas muscles were measured by outlining muscles manually (yellow lines) at the level of the top of the iliac crest (yellow dot line, yellow arrow). Avg, average; Min, minimum; Max, maximum; SD, standard deviation.

according to undernutrition degree; normal (CONUT 0–1), mild (CONUT 2–4), moderate (CONUT 5–8), or severe (CONUT 9–12) (13,14). PNI was calculated using the formula 10× serum albumin (g/dL) + 0.005× total lymphocyte count (per mm^3) [lower PNI is more malnutrition state (15,16)]. NRI was calculated using 1.519 × serum albumin (g/L) + 0.417 × (present body weight/ideal body weight × 100), and ideal body weight was calculated using the gender-specific Acute Respiratory Distress Syndrome Network formulas (men; 50 + (0.91 × [height in centimeters – 152.4]), and women; 45.5 + (0.91 × [height in centimeters – 152.4]) (17). Analysis was performed on PNI and NRI sex-specific quartiles groups, and a lower PNI and NRI quartile indicates a more severe state of malnutrition.

Primary end points of postoperative early outcomes included in-hospital death, infection, and mechanical ventilator (MV) support and ICU stay durations. In-hospital death was defined as death before discharge or ≤30 days after surgery. Infections included sternal wound, urinary tract, and harvest site infections and pneumonia, which were confirmed by culture or specialist consultation when clinical signs were identified. Patients were weaned off the MV as soon as possible when spontaneous breathing of patients was maintained, and arterial blood gas analysis confirmed adequate oxygenation and carbon dioxide level in minimal ventilator settings. Patients were transferred to a general ward from the ICU after their conditions had stabilized and ICU monitoring and treatment were no longer required. Prolonged MV support and ICU stay were defined as ≥24 hours and ≥2 days, respectively.

Statistical analysis

The analysis was conducted using SPSS version 23.0 (Korean version; IBM Corp, New York, NY, USA). The significances of differences between normally distributed continuous variables were determined using the unpaired Student's *t*-test, and results are presented as means ± standard deviations. The significances of differences between non-normally distributed continuous variables were determined using the Mann-Whitney U test, and results are expressed as medians and interquartile ranges. Group variables were analyzed using the Chi-square or Fisher's exact test and are presented as the absolute numbers and percentages. Analysis of variance or Linear by linear association was used to analyze the significances of differences in the distribution of sarcopenia among 4 groups of three nutritional indices. ROC curve analysis was used to identify the nutritional index that best predicted the presence of sarcopenia. All P values provided are 2-sided, and statistical significance was accepted for P values <0.05.

Results

Baseline characteristics and laboratory data

The clinical characteristics and laboratory data of the 499 study subjects are provided in *Tables 1*,*2*. The 124 patients in the sarcopenic group were older, had a lower body weight and body mass index (BMI), a higher EuroSCORE II, and a poorer nutritional status than the 375 patients in the non-sarcopenic group. NRI is significantly lower in male and female sarcopenic group than in non-sarcopenic group, whereas PNI and CONUT were only significantly lower in the male sarcopenic group.

Serum hemoglobin and albumin were lower, but serum neutrophil count, red cell distributive width, and high sensitivity-C reactive protein (hs-CRP) were higher in the sarcopenic group (all P values <0.05).

Clinical outcomes

Operative data and clinical outcomes are summarized in *Table 3*. Duration of MV support and ICU stay was significantly longer in the sarcopenic group (P value =0.008 and 0.001). In-hospital death and infection rates tended to be higher in the sarcopenic group, but these were not statistically significant between the two groups (P values =0.578 and 0.668, respectively).

Table 1 Patient characteristics

Variables	Non-sarcopenic (n=375)	Sarcopenic (n=124)	P value
Age, years	62.0 (53.0, 69.0)	69.0 (58.3, 75.0)	<0.001
Gender (male/female)	220/155 (58.7/41.3)	73/51 (58.9/41.1)	0.968
Body weight, kg	65.70 (58.20, 74.40)	58.90 (52.18, 65.00)	<0.001
Male	70.00 (64.00, 79.05)	63.90 (58.40, 69.45)	<0.001
Female	59.20 (51.20, 64.60)	52.70 (47.00, 56.00)	<0.001
Body surface area, m^2	1.71±0.19	1.63±0.18	<0.001
Male	1.81±0.15	1.73±0.15	<0.001
Female	1.57±0.13	1.49±0.12	0.001
Body mass index, kg/m^2	24.9 (22.8, 27.3)	22.2 (20.4, 23.7)	<0.001
Male	25.1 (23.1, 27.3)	22.8 (20.8, 24.4)	<0.001
Female	24.5 (22.2, 27.3)	21.9 (19.5, 23.0)	<0.001
Comorbidities			
Hypertension	195 (52.0)	64 (51.6)	0.940
Diabetes mellitus	113 (30.1)	35 (28.2)	0.776
Coronary artery disease	66 (17.6)	13 (10.5)	0.060
Cerebral vascular accident	49 (13.1)	20 (16.1)	0.392
Chronic kidney injury	35 (9.3)	19 (15.3)	0.063
Chronic obstructive pulmonary disease	9 (2.4)	8 (6.5)	0.043
Atrial fibrillation	79 (21.1)	24 (19.4)	0.683
Left ventricular ejection fraction, %	58.00 (46.00, 65.00)	58.00 (45.25, 65.00)	0.487
EuroSCORE II, %	1.51 (0.86, 2.62)	2.31 (1.13, 4.80)	<0.001
Psoas muscle area, cm^2	21.55 (15.77, 26.75)	15.00 (10.40, 18.82)	<0.001
Male	25.88 (22.77, 28.79)	18.32 (16.32, 20.08)	<0.001
Female	14.95 (12.97, 16.76)	9.78 (8.84, 10.86)	<0.001
Psoas muscle area index, cm^2/m^2	7.97 (6.53, 9.41)	5.42 (4.25, 6.77)	<0.001
Male	8.95 (8.07, 10.24)	6.62 (5.64, 7.03)	<0.001
Female	3.12 (2.76, 3.51)	2.08 (1.89, 2.29)	<0.001
Prognostic nutritional index	49.40 (45.52, 53.29)	48.20 (43.71, 51.32)	0.013
Male	50.30 (45.73, 53.35)	50.30(45.73, 53.35)	0.011
Female	48.70 (45.09, 53.22)	47.95 (43.57, 53.00)	0.389
CONUT	2.0 (1.0, 3.0)	2.0 (1.0, 3.0)	<0.001
Mean ± standard deviations	1.89±1.67	2.66±2.31	<0.001
Male	1.0 (1.0, 3.0)	2.0 (1.0, 4.0)	0.001
Female	2.0 (1.0, 2.0)	2.0 (1.0, 3.0)	0.123
Nutritional risk index	108.92 (102.98, 115.31)	101.47 (94.65, 107.23)	<0.001
Male	107.03 (101.92, 112.14)	98.78 (93.98, 105.21)	<0.001
Female	111.82 (105.96, 111.35)	104.26 (99.19, 111.35)	<0.001

Data are presented as median (interquartile ranges) or mean ± SD or n (%). CONUT, controlling nutritional status; SD, standard deviation.

Table 2 Patient laboratory data

Variables	Non-sarcopenic (n=375)	Sarcopenic (n=124)	P value
Hemoglobin, g/dL	12.90 (11.50, 14.00)	11.70 (10.23, 13.10)	<0.001
Hematocrit, %	37.80 (33.90, 41.20)	34.95 (31.12, 38.90)	<0.001
Whole blood cell count, $10^3/mm^3$	6.37 (5.16, 7.59)	6.46 (5.43, 8.19)	0.074
Neutrophil, $10^3/mm^3$	3.44 (2.61, 4.40)	3.72 (2.97, 5.31)	0.004
Lymphocyte, $10^3/mm^3$	1.91 (1.48, 2.38)	1.78 (1.42, 2.34)	0.134
Monocyte, $10^3/mm^3$	0.52 (0.41, 0.68)	0.55 (0.42, 0.67)	0.427
Platelet, $10^3/mm^3$	206.00 (165.00, 247.00)	203.00 (166.50, 244.00)	0.683
Red cell distributive width, %	13.00 (12.50, 13.90)	13.30 (12.70, 14.68)	0.012
Total cholesterol, mmol/L	3.98 (3.34, 4.58)	3.81 (3.11, 4.47)	0.068
hs-CRP, mg/L	1.60 (0.80, 5.30)	2.65 (0.93, 6.76)	0.039
Albumin, g/dL	4.00 (3.70, 4.20)	3.90 (3.51, 4.10)	0.015
Total bilirubin, mg/dL	0.61 (0.50, 0.90)	0.70 (0.50, 1.00)	0.184
Aspartate aminotransferase, U/L	26.00 (21.00, 36.00)	25.50 (20.00, 36.75)	0.608
Alanine aminotransferase, U/L	23.00 (17.00, 38.00)	20.50 (13.25, 29.00)	0.001
Blood urea nitrogen, mg/dL	16.10 (12.70, 20.50)	18.10 (13.53, 24.75)	0.004
Creatinine, mg/dL	0.80 (0.66, 1.00)	0.80 (0.60, 1.00)	0.643

Data are presented as median (interquartile ranges). hs-CRP, high sensitivity-C reactive protein.

Optimal nutritional indices for screening the presence of sarcopenia

ROC curve analysis (*Figure 2*) showed that NRI better identified the presence of sarcopenia than CONUT score or PNI (AUC: 0.716, 95% CI: 0.664–0.768, P<0.001). The optimum NRI cut-off value was 105.25, at which NRI had a sensitivity of 67.7% and a specificity of 65.1.

Distribution of sarcopenia according to nutritional indices

Based on the results of a previous CONUT validation study (13), the 499 study subjects were grouped into 4 CONUT score groups, but into PNI and NRI interquartile ranges by gender because of the absence of validation studies (PNI: male; 1Q ≤45.6, 45.6< 2Q ≤49.7, 49.7< 3Q ≤52.8, 52.8< 4Q, female; 1Q ≤45.0, 45.0< 2Q ≤48.6, 48.6< 3Q ≤53.2, 53.2< 4Q) (NRI: male; 1Q ≤98.83, 98.83< 2Q ≤104.78, 104.78< 3Q ≤111.11, 111.11< 4Q, female; 1Q ≤103.44, 103.44< 2Q ≤110.23, 110.23< 3Q ≤117.44, 117.44< 4Q). Sarcopenia proportions in the CONUT and NRI groups differed significantly. However, proportions with sarcopenia differed significantly only between sex-specific NRI quartiles and not between sex-specific PNI quartiles or CONUT groups (P<0.001, *Figure 3*), suggesting NRI might be useful for sarcopenia screening regardless of gender. Of the 124 patients in the first NRI quartile with a malnutritional status, 48.4% were sarcopenia, and this proportion was higher than it was in the first quartile of PNI (31.5%). Based on CONUT score, 47 patients in moderate and severe groups were undernourished, and 20 (42.6%) these patients were sarcopenia.

Duration of MV support and ICU stay according to NRI and the presence of sarcopenia

Odds ratios for prolonged MV support and ICU stay were analyzed in the 4 groups that were divided by NRI and the presence of sarcopenia. Patients in the lowest quartile of NRI were defined as a low NRI. The odds ratio of patients with sarcopenia and low NRI was significantly greater than that of patients without sarcopenia and a high NRI (2.671; P=0.003, P=2.125; P=0.009, respectively, *Tables 4*,*5*).

Table 3 Operative data and clinical outcomes

Variables	Non-sarcopenic (n=375)	Sarcopenic (n=124)	P value
Procedures			
Emergency surgery	23 (6.1)	8 (6.5)	0.899
Previous cardiac surgery	26 (6.9)	14 (11.3)	0.121
CABG	153 (40.8)	41 (33.1)	0.126
Aortic surgery	50 (13.3)	23 (18.5)	0.154
Aortic valve surgery	131 (34.9)	55 (44.4)	0.060
Mitral valve surgery	127 (33.9)	47 (37.9)	0.414
Tricuspid valve surgery	48 (12.8)	21 (16.9)	0.247
Maze procedure	44 (11.7)	6 (4.8)	0.027
Congenital disease	17 (4.5)	2 (1.6)	0.141
Other surgery*	29 (7.7)	9 (7.3)	0.863
Crossclamp time, min	99.00 (75.50, 134.50)	105.00 (82.00, 145.00)	0.203
Cardiopulmonary bypass time, min	147.00 (111.00, 134.50)	152.50 (117.00, 204.50)	0.143
Duration of MV support, hour	16.00 (13.00, 18.00)	17.00 (14.00, 27.75)	0.008
Duration of ICU stay, day	2.00 (2.00, 4.00)	3.00 (2.00, 5.00)	0.001
Complications	193 (51.5)	76 (61.3)	0.057
In-hospital death	22 (5.9)	9 (7.3)	0.578
Infection	72 (19.2)	26 (21.0)	0.668
Prolonged MV support (>24 hr)	56 (14.9)	35 (28.2)	0.002
Duration of ICU stay >2 days	169 (44.7)	72 (60.5)	0.001

Data are presented as median (interquartile ranges) or n (%). *, cardiac surgery for pulmonary valve disease, septal hypertrophy, or benign tumor, such as myxoma. CABG, coronary artery bypass grafting; ICU, intensive care unit; MV, mechanical ventilator.

Clinical outcomes based on BMI and the presence of sarcopenia

Sub-analysis was also performed by dividing patients into the sarcopenic and non-sarcopenic patients groups using a BMI cut-off of 25 kg/m^2 (Tables S2,S3). Unlike non-obese patients, obese sarcopenic patients received MV support and ICU care for significantly longer than obese non-sarcopenic patients. Whereas, unlike obese patients, NRI of non-obese sarcopenic patients was significantly lower than it of non-obese non-sarcopenic patients (obese patients; P=0.784, non-obese patients; P=0.038).

Discussion

Sarcopenia manifests as a generalized, progressive loss of skeletal muscle mass and strength, and is related to metabolic, physiologic, functional impairments, and poor clinical outcomes after various types of surgery (3,18-21). Reduced muscle mass may result in an insidious functional decline, and increase the morbidity and mortality rates after cardiac surgery (1-3,22). Grip strength, chair stand test, and gait speed are used as measuring muscle strength and physical performance in sarcopenia (4). Muscle mass is variously calculated using impedancemetry, MRI, CT, DEXA, and sonography, which are complex, expensive (3,4). Some of these methods are time-consuming and require the ability to walk. Thus, these modalities cannot be applied to some cardiac surgery patients, such as those with acute or aggravated heart failure requiring bed rest or ICU treatment.

Nutritional depletion leads to reductions in muscle mass, and preoperative nutritional status is evaluated using

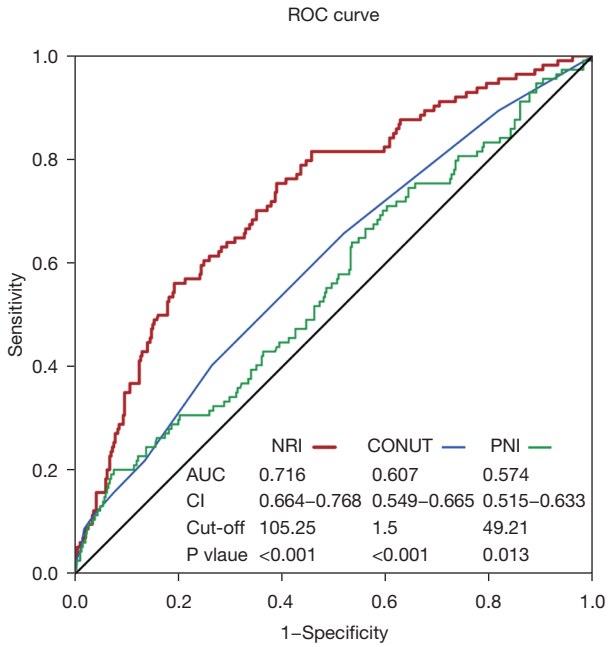
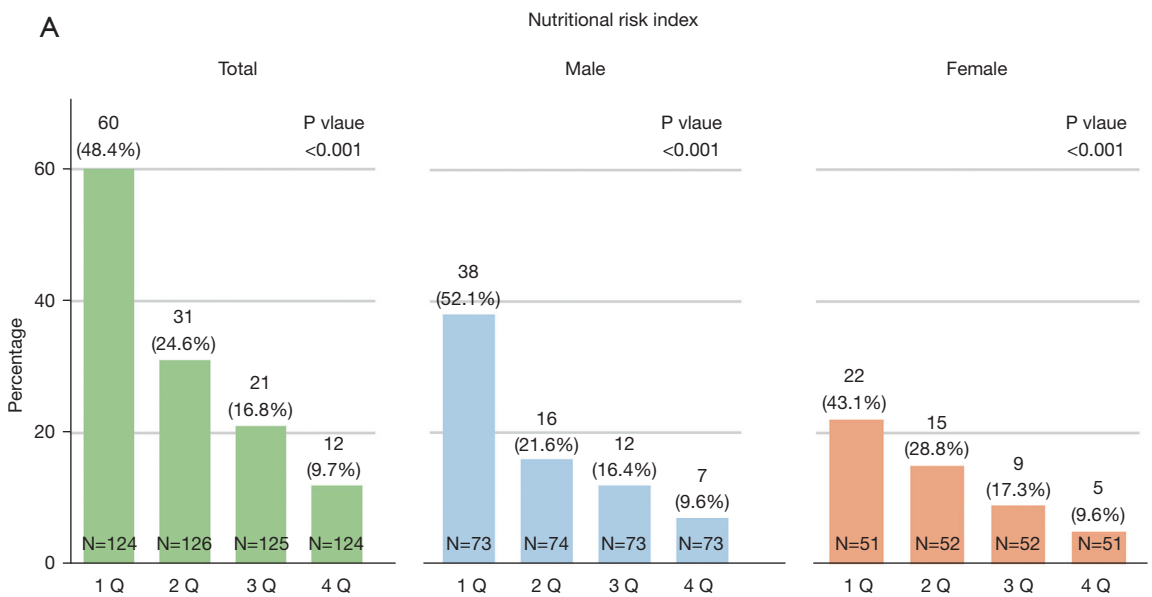


Figure 2 ROC curves of nutritional indices, used to screen for the presence of sarcopenia. NRI better predicted the presence of sarcopenia than CONUT score or PNI. The optimal NRI cut-off was 105.25 and had a sensitivity of 67.7% and a specificity of 65.1%. ROC, receiver operating characteristic; NRI, nutritional risk index; CONUT, controlling nutritional status; PNI, prognostic nutritional index; AUC, area under the curve; CI, confidence interval.

objective nutritional indices. CONUT score, PNI, and NRI can be assessed using simple, reproducible parameters, such as serum albumin and cholesterol levels, total lymphocyte counts, and body weight. Thus, nutritional indices have the potential to be more convenient than conventional methods for assessing sarcopenia, especially in patients needing emergent cardiac surgery or ICU treatment.

This present study reports for the first time that a relation exists between nutritional indices and sarcopenia for adult cardiac surgery patients, and its main finding is that NRI are strongly predictive of the presence of sarcopenia. Furthermore, ROC curve analysis showed that NRI has the sensitivity and specificity needed to screen for sarcopenia before adult cardiac surgery. Comparing that a measure of muscle strength, such as grip strength and chair stand test was used as the first step to a diagnosis of sarcopenia (4), NRI has the merit of being reproducible, less time-consuming, and more straightforward. Furthermore, previous studies have shown that NRI or geriatric NRI are well correlated with muscle strength and dysfunction (23-26).

NRI is calculated from serum albumin level and body weight, which has been originally defined as usual body weight and is replaced with ideal body weight later (27). And, of the three nutritional indices used in the present study, NRI is the only index calculated using body weight, its difference would bring about that NRI could become



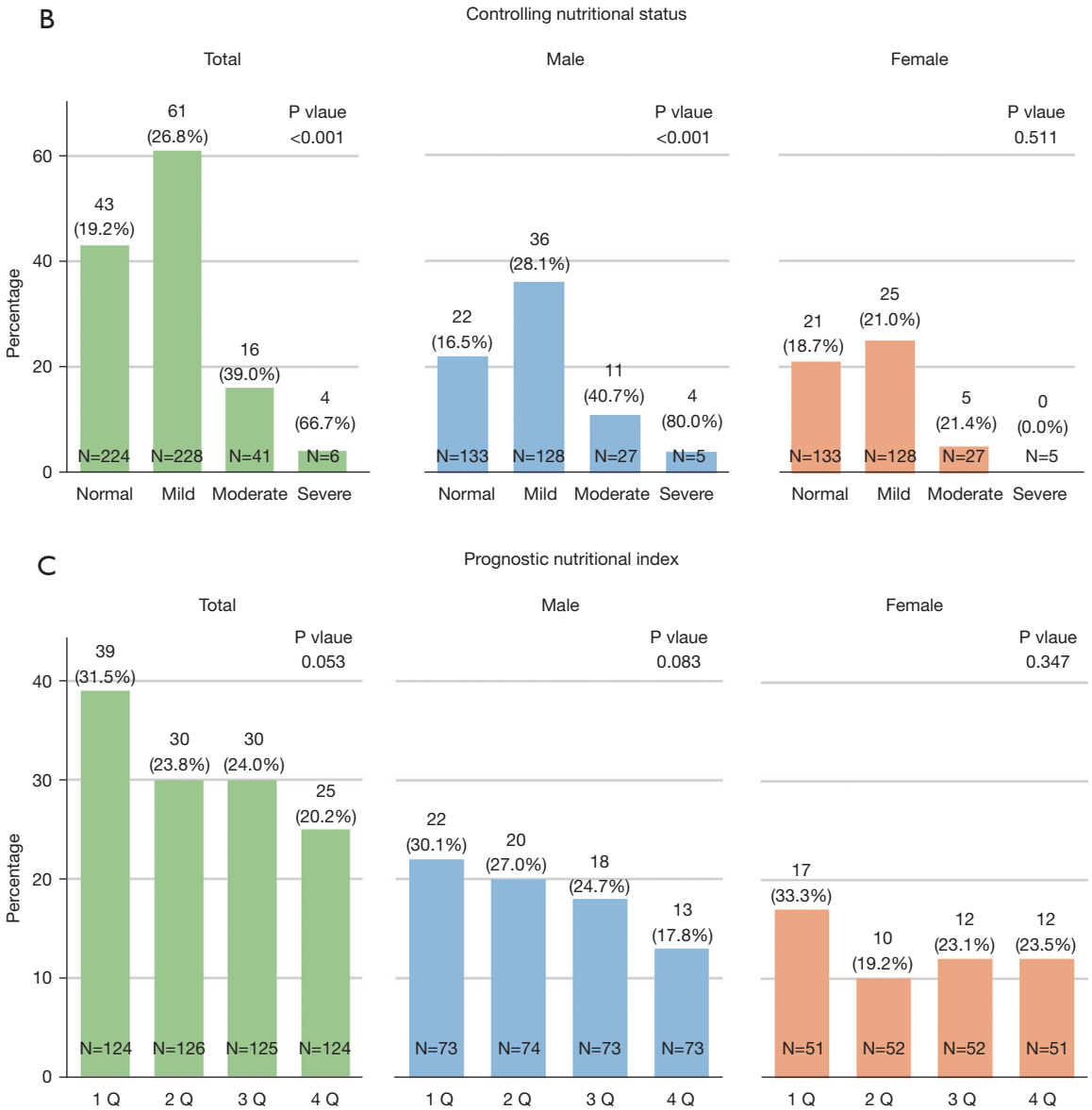


Figure 3 Distribution of sarcopenia by determined using nutritional indices. The distribution of sarcopenia is differed by NRI (A), after CONUT score (B), and PNI (C). The proportion with sarcopenia was higher in the worst nutritional NRI quartile [the first quartile (Q), 48.4%] than in the worst PNI quartile (the first quartile, 31.5%) or those with a moderate-severe CONUT score (42.6%). Proportions of sarcopenic patients differed significantly only for NRI rather than CONUT score or PNI. NRI, nutritional risk index; CONUT, controlling nutritional status; PNI, prognostic nutritional index.

the best screening tool for the presence of sarcopenia. Several previous studies have shown that body weight and BMI are significantly related to the presence of sarcopenia (1,2), which concurs with our result that body weight and BMI were significantly lower in the sarcopenic group. Malnutrition leads to protein degradation and suppresses protein synthesis and thus may cause albumin deficiency and make NRI lower. It has been associated with low muscle strength and mass (23-26).

In addition, NRI has been reported to be related to inflammation (28,29), we found neutrophil count, red cell distributive width, and high sensitivity-C reactive protein

Table 4 The OR of incidence for prolonged mechanical ventilator support

Category	Prolonged MV support (>24 hr)	OR (95% CI)	P value
Non-sarcopenia, high NRI (n=311)	43 (13.8%)	1	NA
Sarcopenia, high NRI (n=64)	17 (26.6%)	1.589 (0.798–3.164)	0.188
Non-sarcopenia, low NRI (n=64)	13 (20.3%)	2.254 (1.187–4.281)	0.013
Sarcopenia, low NRI (n=60)	18 (30.0%)	2.671 (1.410–5.062)	0.003

OR, odds ratio; MV, mechanical ventilator; NRI, nutritional risk index; NA, not available.

Table 5 The OR of incidence for intensive care unit stay

Category	Duration of ICU stays >2 days	OR (95% CI)	P value
Non-sarcopenia, high NRI (n=311)	134 (43.1%)	1	NA
Sarcopenia, high NRI (n=64)	35 (54.7%)	1.594 (0.928–2.738)	0.091
Non-sarcopenia, low NRI (n=64)	35 (54.7%)	1.594 (0.928–2.738	0.091
Sarcopenia, low NRI (n=60)	37 (61.7%)	2.125 (1.206–3.745)	0.009

OR, odds ratio; ICU, intensive care unit; NRI, nutritional risk index; NA, not available.

were significantly higher in the sarcopenic group. These results also suggest that NRI could be useful for sarcopenia screening. Furthermore, sarcopenia increases oxidative stress and systemic inflammation due to reduced protein synthesis and increased protein degradation. As a vicious circle, increased systemic inflammation exacerbates muscle mass loss and sarcopenia. Previous studies have indicated that there may be a correlation between NRI and sarcopenia for these reasons, particularly in patients with chronic kidney disease, advanced age, and type 2 diabetes (23-26,30).

The present study shows that the durations of MV support and ICU stay in the sarcopenic group were greater than in the non-sarcopenic group, which agrees with a previous report (2). Poor nutritional status might also result in weak respiratory muscle function. In our study, sarcopenic patients with lower NRI had significantly greater MV support and ICU stay durations, which suggests that preoperative nutritional intervention before cardiac surgery might reduce MV support and ICU stay duration. Previous studies on nutritional intervention for patients with sarcopenia have also reported that nutritional support can improve muscle mass and function (31,32). These finding raise the possibility that NRI might also be useful for identifying patients who need nutritional intervention before cardiac surgery. Our results also showed patients with sarcopenia and a lower NRI had significantly longer MV support and ICU stay durations than patients with only one factor of sarcopenia or low NRI. It indicates that longer MV support and ICU stay duration might be better predicted when NRI and the presence of sarcopenia are identified together.

Subgroup analysis based on BMI revealed that sarcopenic obesity (obese sarcopenic patients) was related to longer MV support and ICU care after adult cardiac surgery. Previous studies have shown that sarcopenic obesity is associated with adverse clinical outcomes after cardiac surgery (33,34). The authors also commented that adipose tissue produces inflammatory cytokines, which are related to adverse clinical outcomes.

Study limitations

This study has several limitations. First, it is inherently limited by its observational, retrospective design. Second, although we measured bilateral psoas muscle mass in the same manner as that used in previous cardiac surgery studies (1), the prevalence of sarcopenia found in the present study may differ from that previously reported from total abdominal skeletal muscle mass (35). Psoas muscle areas may be less representative of overall muscle condition, even if they are easily measured rather than total abdominal skeletal muscle mass. Third, sarcopenia was defined as a psoas muscle area index in the lowest sex-specific quartile as performed in previous studies because of

the lack of a universal definition. Forth, currently, there are no validate cut-off values of the relationship between NRI and sarcopenia available for adult cardiac surgery patients. We utilized a quartile classification approach, commonly used. Finally, muscle strength and physical performance were not investigated because data were unavailable. In the future, prospective well-designed, and large-scale studies are required for a universal definition of sarcopenia and the relationship between muscle strength and NRI in adult cardiac surgery patients.

Conclusions

Malnutrition causes sarcopenia, and nutritional indices could be used to screen for sarcopenia. NRI provides a better means of screening for sarcopenia among adult cardiac surgery patients than CONUT score or PNI. And NRI is considerably more straightforward and faster than muscle strength or mass measurements, and then would be an alternative to the conventional methods in all adult cardiac surgery patients.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of the Gil Medical Center (No. GDIRB2022-055), and individual consent for this retrospective analysis was waived.

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Supplementary

Table S1 Assessment of degree of undernutrition using CONUT score

Parameter	Undernutrition degree			
	Normal	Light	Moderate	Severe
Serum Albumin (g/dl)	3.5–4.5	3.0–3.49	2.5–2.9	<2.5
Score	0	2	4	6
Total Lymphocytes/ml	>1,600	1,200–1,599	800–1,199	<800
Score	0	1	2	3
Cholesterol (mg/dl)	>180	140–180	100–139	<100
Score	0	1	2	3
Screening Total Score	0–1	2–4	5–8	9–12

CONUT, COntrolling NUTritional status.

Table S2 Clinical data of patients with a BMI <25 Kg/m^2

Variables	Non-sarcopenic (225)	Sarcopenic (75)	P value
Psoas muscle area, cm^2, median (IQR)	21.92 (15.71, 27.71)	14.57 (10.02, 19.07)	<0.001
Psoas muscle area index, cm^2/m^2, median (IQR)	8.32 (6.01, 10.53)	5.33 (3.74, 7.47)	<0.001
Nutritional risk index, median (IQR)	103.71 (98.08, 108.89)	101.09 (94.53, 107.59)	0.038
Duration of MV support, hour, median (IQR)	16.50 (14.00, 24.00)	16.00 (12.50, 18.00)	0.018
Duration of ICU stays, day, median (IQR)	3.00 (2.00, 5.00)	2.00 (2.00, 3.50)	0.079
Complications, n (%)	115 (51.1)	45 (60.0)	0.181
In-hospital death, n (%)	15 (6.7)	3 (4.0)	0.576
Infection, n (%)	45 (20.0)	16 (21.3)	0.804
Prolonged MV support (>24 hr), n (%)	31 (13.8)	18 (24.0)	0.109
Duration of ICU stay >2 days, n (%)	99 (44.0)	41 (54.7)	0.038

BMI, body mass index; ICU, intensive care unit; IQR, interquartile ranges; MV, mechanical ventilator.

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Table S3 Clinical data of patients with a BMI ≥ 25 kg/m^2

Variables	Non-sarcopenic (150)	Sarcopenic (49)	P value
Psoas muscle area, cm^2, median (IQR)	21.08 (15.96, 25.82)	15.50 (11.10, 18.60)	<0.001
Psoas muscle area index, cm^2/m^2, median (IQR)	7.85 (5.97, 9.82)	5.73 (4.29, 7.21)	<0.001
Nutritional risk index, median (IQR)	113.15 (108.24, 119.51)	113.38 (105.04, 120.45)	0.784
Duration of MV support, hour, median (IQR)	16.00 (13.00, 19.00)	17.00 (14.50, 39.00)	0.023
Duration of ICU stays, day, median (IQR)	2.00 (2.00, 4.00)	3.00 (2.00, 5.00)	0.049
Complications, n (%)	78 (52.0)	31 (63.3)	0.169
In-hospital death, n (%)	7 (4.7)	6 (12.2)	0.091
Infection, n (%)	27 (18.0)	10 (20.4)	0.707
Prolonged MV support (>24 hr), n (%)	25 (16.7)	17 (34.7)	0.007
Duration of ICU stay >2 days, n (%)	70 (46.7)	31 (63.3)	0.044

BMI, body mass index; ICU, intensive care unit; IQR, interquartile ranges; MV, mechanical ventilator.

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