



Effects of postoperative dietary intake on functional recovery of patients undergoing cardiac surgery

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Abstract *Background and aim:* Among elderly patients undergoing cardiac surgery, malnutrition is very common and related to muscle wasting known as sarcopenia. Cardiac surgery causes a further decline of nutritional status due to reduced dietary intake (DI); however, the impact of postoperative DI on functional recovery is unclear.

Methods and results: We enrolled 250 consecutive patients undergoing cardiac surgery. Daily DI was measured between postoperative days 3 and 7. Patients were categorized as having sufficient or insufficient DI based on whether their DI met or was less than estimated total energy requirements. Functional capacity was measured using the 6-minute walking distance (6MWD) preoperatively and at discharge. Mean postoperative DI was 22.4 ± 3.0 kcal/kg/day, and postoperative DI was insufficient in 92 patients (36.8%). The prevalence of sarcopenia was not different by postoperative DI. Although there was no significant difference in preoperative 6MWD results ($P = 0.65$), the sufficient DI group had longer 6MWD at discharge than the insufficient DI group ($P = 0.04$). In multivariate regression analysis, preoperative poor nutritional status ($\beta = -0.29$), duration of surgery ($\beta = -0.18$), and postoperative DI ($\beta = 0.40$) remained statistically significant predictors for improvement of 6MWD ($P < 0.0001$, adjusted $R^2 = 0.41$). *Conclusions:* Postoperative DI was independently associated with functional recovery, but preoperative sarcopenia was not. Regardless of preoperative nutritional status or the presence of sarcopenia, aggressive nutritional intervention in the early stage after surgery helps support functional recovery.

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Introduction

As a result of increasing life expectancy and the higher incidence of cardiovascular diseases associated with aging, the demand for cardiac surgery in the elderly is growing [1]. Malnutrition is commonly seen in the elderly with heart failure and is associated with greater mortality; thus, it is a problem that requires a solution [2–4].

Poor nutritional status can also be related to the catabolic state and muscle wasting known as “sarcopenia” and is reported to be a predictor of long-term survival after cardiothoracic surgery [5,6]. We previously reported that poor preoperative nutritional status is associated with muscle wasting and is a predictor of the retardation of functional recovery after cardiac surgery [7].

Cardiac surgery can cause a further decline in nutritional status due to postoperative catabolic reaction and a decrease in dietary intake (DI) [8]. Previous studies reported that approximately 0.90 g/dL of serum albumin was lost in the perioperative period [9,10]. Although it remains unclear whether this significant decline in albumin is due to poor nutritional status or the catabolic reactions from surgery, postoperative DI is thought to be reduced due to loss of appetite or lack of taste. A previous study found that 58% of patients after cardiac surgery reported loss of appetite in the hospital and complained about dysgeusia possibly induced by anesthesia or mechanical ventilation [11]. Nevertheless, only a few clinical studies have focused on DI after cardiac surgery. Ingadottir et al. [12] showed that postoperative DI met only 74.4% of their patients' estimated energy requirements at day 5 after cardiothoracic surgery. Furthermore, decreased DI after surgery has been reported to lead to chronic malnutrition and increased mortality [13].

To our knowledge, no clinical studies have investigated the impact of DI on functional recovery as a predictor of adverse cardiac events after cardiac surgery. Functional recovery is a matter of extreme importance because functional capacity at discharge after cardiac surgery is reported to predict adverse cardiac events over the next one year [14].

We therefore hypothesized that both preoperative muscle wasting of sarcopenia and postoperative DI would be predictors of functional recovery after cardiac surgery. Thus, the purpose of the present study was to investigate the effect of preoperative sarcopenia or postoperative DI on functional recovery in cardiac surgery patients.

Methods

Study population

Between July 2015 to January 2017, we screened 278 consecutive patients admitted to Kobe University Hospital. We enrolled a cohort of inpatients in whom cardiopulmonary bypass was used in procedures such as valve replacement or repair or coronary artery bypass grafting (CABG) with concomitant valve replacement or repair. Exclusion criteria included patients whose functional

capacity was not measured due to neurological or orthopedic disease; those with severe dementia, and those in whom postoperative DI could not be assessed or oral intake could not be initiated within 3 days after surgery due to postoperative complications prohibiting dietary intake such as prolonged ventilation, stroke, or septic shock. All patients began postoperative rehabilitation starting the day after the surgery in accordance with the Japanese Circulation Society guidelines for rehabilitation in patients with cardiovascular disease [15]. We examined the initiation of postoperative mobilization exercises consisting of getting out of bed (sitting on the edge of the bed), standing at bedside, walking around the bed, and 100-m walk as early postoperative rehabilitation. After that, we prescribed a physical training program that included a personalized aerobic exercise program and resistance exercises. Aerobic exercise involved a half hour monitored cycle ergometer or treadmill walking training at the intensity of 11–13 on Borg scale. Muscle and endurance exercises consisted of sit-to-stand and heel lifting exercises with increasing number of repetitions. Physical training was initiated in a hospital setting and supervised by a physiotherapist. The present study complied with the principles of the Declaration of Helsinki regarding investigations in human subjects and was approved by the Kobe University Institutional Review Board. Written informed consent was obtained from each patient before their cardiac surgery.

Clinical characteristics of the patients

Baseline characteristics evaluated included age, sex, body mass index (BMI), left ventricular ejection fraction, estimated glomerular filtration rate, the level of brain natriuretic peptide, hemoglobin, serum albumin, and C-reactive protein (CRP), comorbidities, medications, and operative risk scores such as the European System for Cardiac Operative Risk Evaluation (EuroSCORE) II [16]. Laboratory data were evaluated within 1 week before cardiac surgery and just before discharge. Operative clinical variables recorded included the type of cardiac surgery and the duration of surgery, cardiopulmonary bypass time, and aortic cross-clamp time in minutes. Postoperative clinical variables recorded included hospital mortality, length of the intensive care unit (ICU) stay, length of hospital stay, and postoperative complications associated with surgery.

Assessment of baseline nutritional status and postoperative dietary intake

Nutritional status at baseline was assessed using the Mini Nutritional Assessment Short-Form (MNA-SF). The reliability and validity of the MNA-SF have already been proven for the detection of malnutrition [17]. Postoperative daily DI was measured from postoperative day 3 to day 7. Assessment of DI was conducted using the visual estimation method as described elsewhere [18] by a trained nurse worked independently of this study. DI was

assessed on a scale of 0–10 for each component of the meal (e.g., soup, vegetables, rice). All meals were converted to energy and protein intake based on the food composition of each meal. Some patients were managed using peripheral parenteral nutrition for fluid management and electrolyte balance after surgery, and their energy intake was calculated from their medical records. We assessed daily DI of both energy and proteins. Individual basal energy expenditure (BEE) was calculated using the Harris-Benedict formula [19]. In the calculation, we used the ideal body weight for patients with a BMI ≥ 25.0 kg/m² because the BEE of these patients was overestimated by the weight-based Harris-Benedict formula [20].

Assessment of sarcopenia and functional capacity

Sarcopenia was defined as low muscle mass plus low muscle strength and/or low physical performance according to the definition of the Asian Working Group for Sarcopenia [21]. Muscle mass was estimated by dividing the cross-sectional areas of the left and right psoas muscles at the level of the transverse process of L3 from plain CT imaging by the height squared. A CT scan was routinely performed for all patients on admission during the inpatient period and at least within one week before surgery. Low muscle mass was defined as a value of less than 6.36 cm²/m² for men and 4.40 cm²/m² for women according to a previous study [22]. The low muscle strength and low physical performance were defined as handgrip strength of <26 kg for men and <18 kg for women and a usual gait speed of <0.8 m/s, respectively. We used the 6-minute walking distance test (6MWD), a submaximal exercise test, to assess functional capacity. The 6MWD was performed according to the American Thoracic Society guidelines [23] in a 30-m-long straight corridor under the guidance of a physiotherapist. For this test, participants were instructed to walk at a self-selected pace with the aim of covering as much distance as possible in 6 min. We assessed 6MWD before surgery and just before discharge after surgery. Absolute functional gain (discharge 6MWD score – preoperative 6MWD score) was calculated to evaluate the change in perioperative functional capacity.

Statistical analysis

We conducted statistical analyses after confirming that the data were normally distributed using the Shapiro–Wilk test. Patients were stratified into two groups according to postoperative DI. Patients whose DI met energy requirements (DI/BEE ≥ 1) were categorized into the sufficient DI group, and those whose DI did not meet the energy requirements (DI/BEE < 1) were categorized into the insufficient DI group. We compared clinical characteristics between the two groups using an independent *t*-test or chi-square test. Two-way repeated measures analysis of variance was used to compare the effects of DI (sufficient DI group vs. insufficient DI group)

on functional recovery between before and after surgery. The within-subject factor was time (time effect), and the between-subject factor was group (group effect). A multiple regression analysis was used to examine the association between the change of functional recovery and each clinical characteristic. In this analysis, the change of functional capacity was used as the dependent variable, whereas the independent variables included postoperative DI and other clinical characteristics. Confounding factors were selected as those that were significantly different between the two groups at $P < 0.10$ in bivariate analyses. A P value of < 0.05 was considered to show statistical significance. Statistical analyses were carried out with JMP11.0J software (SAS Institute Japan, Tokyo, Japan).

Results

Of the 278 patients, 28 were excluded from the study based on the exclusion criteria. Among these 28 excluded patients, DI could not be assessed completely due to postoperative complications in 19, 2 had neurological disease, 3 had orthopedic issues, 3 had severe dementia, and 1 died in the hospital. Thus, 250 patients with a mean age of 67.5 ± 13.1 years were the subjects of the present study. We divided these patients into the sufficient DI group (DI/BEE ≥ 1 ; $n = 158$, 63.2%) and insufficient DI group (DI/BEE < 1 ; $n = 92$, 36.8%). Baseline characteristics stratified by postoperative DI are shown in Table 1. Patients in the insufficient DI group were significantly younger than those in the sufficient DI group ($P = 0.0085$). However, preoperative MNA-SF score, prevalence of sarcopenia, and other preoperative clinical laboratory data or comorbidities were not significantly different between the two groups. Among the perioperative factors, duration of surgery, CPB and aortic cross-clamp time were significantly longer in the insufficient DI group than in the sufficient DI group ($P < 0.05$ for each).

The mean DI and protein intake of all patients were 22.4 ± 9.3 kcal/kg and 0.9 ± 0.4 g/kg, respectively (Table 2). Both were significantly lower in the insufficient DI group versus the sufficient DI group (DI: 14.8 ± 5.2 vs. 26.8 ± 8.2 kcal/kg/day; protein intake: 0.6 ± 0.2 vs. 1.0 ± 0.2 g/kg/day; $P < 0.0001$ for each). The timing of initiating DI after surgery was not statistically different between the two groups. ($P = 0.31$).

Table 3 shows a comparison of the 6MWD and nutritional status before and after surgery. There was no significant difference in the preoperative 6MWD between the two groups ($P = 0.65$), whereas the sufficient DI group achieved a significantly longer 6MWD than the insufficient DI group at discharge ($P = 0.04$). The 6MWD showed a significant interaction ($F = 15.8$; $P < 0.0001$) and main effects of time between the two groups ($P < 0.05$). There was no significant interaction on CRP level and serum hemoglobin level; however, there were significant main effects of time ($P < 0.05$ for each). The CRP levels significantly increased after surgery, although serum hemoglobin significantly decreased in both groups. With regard to

Table 1 Baseline characteristics of the patients according to postoperative DI/BEE groups.

| Characteristic | Total | Sufficient DI | Insufficient DI | t or χ^2 value | P value |
|------------------------------------|---------------|---------------|-----------------|---------------------|---------|
| Number, n (%) | 250 | 158 (63.2) | 92 (36.8) | | |
| Age, years | 67.5 ± 13.1 | 69.4 ± 11.7 | 64.3 ± 14.8 | 2.66 | 0.009 |
| Female, n (%) | 112 (44.8) | 63 (39.9) | 49 (53.3) | 3.36** | 0.067 |
| Body mass index, kg/m ² | 23.2 ± 3.9 | 23.2 ± 3.8 | 23.3 ± 4.3 | -0.04 | 0.96 |
| Comorbidities, n (%) | | | | | |
| Atrial fibrillation | 56 (22.4) | 35 (22.1) | 21 (22.8) | 0.02 | 0.886 |
| Hypertension | 114 (45.6) | 72 (45.6) | 42 (45.7) | 0.00** | 0.951 |
| Dyslipidemia | 61 (24.4) | 35 (22.2) | 26 (28.3) | 0.99** | 0.319 |
| Diabetes mellitus | 56 (22.4) | 35 (22.2) | 21 (22.8) | 0.02** | 0.886 |
| Euroscore II | 6.3 ± 2.8 | 6.5 ± 2.5 | 5.6 ± 2.4 | 1.80 | 0.075 |
| Ejection fraction, % | 61.6 ± 11.3 | 61.6 ± 12.0 | 61.5 ± 10.0 | 0.07 | 0.947 |
| Laboratory data | | | | | |
| BNP, pg/mL | 221.9 ± 327.7 | 220.5 ± 318.0 | 224.4 ± 345.3 | 1.21 | 0.229 |
| eGFR, mL/min/1.73 m ² | 58.7 ± 20.4 | 58.9 ± 18.8 | 58.4 ± 23.1 | 0.18 | 0.859 |
| Hemoglobin, g/dL | 12.8 ± 1.83 | 12.8 ± 1.83 | 12.8 ± 1.84 | 0.07 | 0.947 |
| Albumin, g/dL | 3.98 ± 0.48 | 3.96 ± 0.45 | 4.02 ± 0.53 | -0.86 | 0.388 |
| CRP, mg/dL | 0.35 ± 0.90 | 0.39 ± 0.98 | 0.28 ± 0.77 | 0.82 | 0.413 |
| Medication, n (%) | | | | | |
| β -blocker | 117 (46.8) | 79 (50.0) | 38 (41.3) | 1.25** | 0.263 |
| ACE-I/ARB | 136 (54.4) | 89 (56.3) | 47 (51.0) | 1.78** | 0.182 |
| CCB | 67 (26.8) | 44 (27.8) | 23 (25.0) | 0.10** | 0.752 |
| Diuretics | 75 (25.0) | 46 (29.1) | 29 (31.5) | 0.11** | 0.735 |
| Types of surgery, n (%) | | | | | |
| Aortic valve | 74 (29.6) | 48 (30.4) | 26 (28.3) | 0.37** | 0.95 |
| Mitral valve | 97 (38.8) | 61 (38.6) | 36 (39.1) | — | — |
| Mitral & Aortic valve | 29 (11.6) | 17 (10.8) | 12 (13.0) | — | — |
| Valve + CABG | 50 (20.0) | 32 (20.3) | 18 (19.6) | — | — |
| Duration of surgery, min | 354.3 ± 138.3 | 323.6 ± 89.6 | 382.0 ± 138.0 | -3.60 | 0.0004 |
| Duration of CPB, min | 173.6 ± 62.0 | 167.0 ± 59.4 | 184.9 ± 65.0 | -1.95 | 0.026 |
| Aortic cross-clamp time, min | 110.0 ± 52.7 | 104.7 ± 46.9 | 118.8 ± 60.3 | -1.76 | 0.039 |
| Sarcopenia, n (%) | 68 (27.2) | 36 (22.8) | 32 (34.8) | 1.51** | 0.093 |
| MNA-SF, n (%) | | | | | |
| Well nourished | 154 (61.6) | 101 (63.9) | 53 (57.6) | 1.61** | 0.448 |
| At risk | 76 (30.4) | 43 (27.2) | 33 (35.9) | — | — |
| Malnutrition | 20 (8.0) | 14 (8.9) | 6 (6.5) | — | — |

DI, dietary intake; BEE, basal energy expenditure; BNP, brain natriuretic peptide; eGFR, estimated glomerular filtration rate; CRP, C-reactive protein; ACE-I, angiotensin converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CCB, calcium channel blocker; CABG, coronary artery bypasses grafting; CPB, cardiopulmonary bypass; MNA-SF, Mini Nutritional Assessment-Short Form.

Data are expressed as mean ± standard deviation or number (percentage).

** χ^2 value.

BMI and serum albumin, both were significantly decreased after surgery ($p < 0.05$ for each). In addition, postoperative serum albumin levels in the sufficient DI group were significantly higher than those in the insufficient DI group ($P = 0.039$). There were also significant terms by group interactions for BMI and serum albumin, respectively ($P < 0.05$ for each).

The results of multiple regression analyses for predicting improvement of 6MWD are shown in Table 4. After adjusting for all confounding factors, preoperative malnutrition as defined by the MNA-SF score ($\beta = -0.29$), duration of surgery ($\beta = -0.18$), and postoperative DI ($\beta = 0.40$) remained statistically significant predictors for improvement of 6MWD ($P < 0.0001$, adjusted $R^2 = 0.41$).

Table 2 Clinical course of the patients according to postoperative DI/BEE groups.

| | Total | Sufficient DI | Insufficient DI | t value | P value |
|-------------------------------|----------------|----------------|-----------------|---------|---------|
| Number, n (%) | 250 | 158 (63.2) | 92 (36.8) | | |
| Length of ICU stay, days | 2.4 ± 3.0 | 2.8 ± 1.0 | 2.2 ± 1.3 | -2.70 | 0.007 |
| Length of hospital stay, days | 21.5 ± 15.7 | 18.1 ± 9.9 | 27.4 ± 21.3 | 4.89 | <0.001 |
| Timing of initiating DI, days | 1.4 ± 0.5 | 1.4 ± 0.5 | 1.4 ± 0.7 | 1.15 | 0.310 |
| BEE, kcal/day | 1241.3 ± 221.0 | 1223.0 ± 198.3 | 1272.6 ± 253.6 | -1.53 | 0.128 |
| DI, kcal/day | 1275.0 ± 405.1 | 1514.7 ± 212.0 | 864.6 ± 318.0 | 27.00 | <0.0001 |
| DI, kcal/kg/day | 22.4 ± 9.3 | 26.8 ± 8.2 | 14.8 ± 5.2 | 11.30 | <0.0001 |
| Protein intake, g/kg/day | 0.9 ± 0.4 | 1.0 ± 0.2 | 0.6 ± 0.2 | 5.80 | <0.0001 |

DI, dietary intake; BEE, basal energy expenditure; ICU, intensive care unit.

Data are expressed as mean ± standard deviation.

Table 3 Comparisons of changes in 6MWD and nutritional status.

| Variables | Sufficient DI | Insufficient DI | P value ^a | Interaction | |
|--------------------------|------------------|-----------------|----------------------|-------------|----------------------|
| | | | | F value | P value ^b |
| 6MWD (m) | | | | | |
| Pre | 414.97 ± 111.23 | 422.79 ± 108.48 | 0.65 | 15.82 | <0.0001 |
| Post | 369.72 ± 113.85* | 335.13 ± 96.52* | 0.04 | – | – |
| BMI (kg/m ²) | | | | | |
| Pre | 23.22 ± 3.77 | 23.25 ± 4.22 | 0.97 | 6.21 | 0.01 |
| Post | 22.29 ± 3.14* | 21.76 ± 4.01* | 0.31 | – | – |
| CRP (mg/dL) | | | | | |
| Pre | 0.39 ± 0.98 | 0.28 ± 0.77 | 0.41 | 0.04 | 0.84 |
| Post | 2.49 ± 3.08* | 2.51 ± 2.42* | 0.97 | – | – |
| Hemoglobin (g/dL) | | | | | |
| Pre | 12.77 ± 1.83 | 12.75 ± 1.84 | 0.95 | 1.39 | 0.24 |
| Post | 10.34 ± 1.11* | 10.00 ± 0.99* | 0.03 | – | – |
| Albumin (g/dL) | | | | | |
| Pre | 3.96 ± 0.45 | 4.02 ± 0.53 | 0.39 | 5.56 | 0.02 |
| Post | 3.12 ± 0.35* | 3.01 ± 0.38* | 0.04 | – | – |

6MWD, six-minute walking distance; DI, dietary intake; BMI, body mass index; CRP, C-reactive protein.

*P < 0.05 Significance level for the hypothesis of time effect (pre vs. post in the same group).

^a Significance level for the hypothesis of no group effect (sufficient DI vs. insufficient DI).

^b Significance level for the hypothesis of no time × group effect.

Table 4 Multivariate regression analysis for predicting improvement of 6MWD.

| | Improvement of 6MWD (R ² = 0.41, P < 0.0001) | |
|-------------------------------|--|---------|
| | β | p value |
| Age | −0.02 | 0.97 |
| Sex, (ref. Female) | 0.03 | 0.68 |
| BMI | 0.16 | 0.06 |
| Sarcopenia | −0.08 | 0.63 |
| DI | 0.40 | <0.001 |
| MNA-SF, (ref. Well nourished) | | |
| At risk | −0.11 | 0.18 |
| Malnutrition | −0.29 | 0.031 |
| Duration of surgery | −0.18 | 0.04 |

6MWD, six-minute walking distance; BMI: body mass index; DI: dietary intake; MNA-SF: Mini Nutritional Assessment-Short Form.

Discussion

To the best of our knowledge, this is the first study to show a relationship between DI and functional recovery in patients after cardiac surgery. We showed that postoperative DI was independently associated with functional recovery after adjustment for confounding variables. However, there was no significant relationship between preoperative sarcopenia and improvement in the 6MWD.

In this study, the mean DI for the 5 days from postoperative day 3–7 after surgery was 1241.3 ± 221.0 kcal/day, with 36.8% of the patients not meeting their energy requirements. Among the studies on DI after cardiac surgery, Vilhjálmsdóttir et al. [24] reported that 80% of patients were not able to meet the required energy level on the fifth day after surgery. Ingadóttir et al. [12] found that DI for the first 3–5 days after cardiac surgery was 1452 ± 389 kcal/day, which was higher than that of our study. This could be explained by the difference in race or

body size (average BMI was 23.0 kg/m² in the present study versus 27.0 kg/m² in the previous study).

Another study found female sex and low BMI to be risk factors for reduced DI [25]. Consistent with these findings, the DI in the women in the present study tended to decrease in comparison to that of the men, although the difference was not statistically significant. In contrast, preoperative BMI did not appear to have an effect on postoperative DI. Generally, DI and protein intake correlate with whole body muscle mass, and DI plays a particularly important role in protein metabolism and muscle wasting [26]. Although loss of appetite called anorexia is accepted as the main driver for lower dietary intakes, anorexia is a multifactorial process and its etiology was not fully understood. However, cardiac surgery can induce severe nausea or failure of salivary secretion and taste abnormalities due to intubation, anesthesia and inflammation. Furthermore, loss of appetite can also be related to gastrointestinal dysfunction and postoperative pain. Management of these related symptoms should be included to achieve an optimal nutritional intake and early detection of decreasing dietary intake and treatment is desirable. In any cases, the dietary intake is a modified factor; adequate intervention and tailor-made treatment improves dietary intake and enhance functional recovery. However, our results showed that preoperative nutritional status and sarcopenia were unrelated to postoperative DI. It is conceivable that after highly invasive surgery, surgical stress and inflammation more strongly affect DI than preoperative chronic malnutrition or muscle wasting. Our results may pave the way for further studies that elucidate the factor(s) having the most impact on postoperative DI.

To our knowledge, there are no reports on the effect of postoperative DI on functional capacity. Although DI and protein intake before surgery are reported to predict postoperative complications, there are no reports mentioning postoperative DI. In our results, postoperative

DI was independently associated with functional recovery. The catabolism of protein is a key mechanism to explain the perioperative change of functional capacity. Insufficient DI can result in prolongation of the catabolic reaction and a further decline in nutritional status. In addition, it is known that prolonged hypercatabolism leads to the degradation of skeletal muscle, which imposes short- and long-term burdens for functional recovery [27]. The Guidelines on Clinical Nutrition from the European Society for Clinical Nutrition and Metabolism (ESPEN) recommend that during the anabolic recovery phase, the target energy supply should be 25–30 kcal/kg/day [28]. In our results, the mean DI in the insufficient DI group was just 14.8 kcal/kg/day, which is far off the recommended value.

Other than DI, possible factors that induced catabolic reactions were operative stress and preoperative malnutrition, which were found to be predictive factors for improvement of the 6MWD in our multivariate analysis (Table 4). It was reported that reducing operative stress in elective surgery could minimize catabolism, support anabolism throughout the surgical treatment, and facilitate early recovery [29]. It is our belief that the effects of anesthesia and CPB lead to increase systemic inflammatory response, accelerate catabolic state, and result in upregulated muscle proteolysis and decreasing functional recovery. In addition, it was reported that preoperative malnutrition was associated with postoperative mortality and major morbidity due to increased catabolism and metabolic requirements [30]. However, in the present study, the presence of preoperative sarcopenia did not predict functional recovery. This suggests that pre- and postoperative nutrition regulate functional recovery during the perioperative period rather than existing muscle wasting or a decline in physiological reserve. The previous study showed that nutritional intervention in malnourished hospitalized patients with heart failure reduces the risk of death from any cause and the risk of readmission for worsening of heart failure [31]. Especially, the administration of oral immune-enhancing nutritional supplement for 5 days preoperatively improved preoperative immune function, decreased interleukin 6 levels, and reduced the incidence of postoperative infections [32]. Another study showed that oral amino acid supplementation, in conjunction with standard pharmacologic therapy, appears to increase exercise capacity by improving circulatory function, muscle oxygen consumption, and aerobic production of energy in elderly outpatients with heart failure [33]. Furthermore, a high proportion of leucine is required for optimal stimulation of the rate of muscle protein synthesis by essential amino acids in the elderly [34]. Thus, we highly recommend a preoperative immune-enhancing nutritional supplement or amino acid supplementation for its great potential to improve the postoperative prognosis and functional recovery.

There are several limitations in this study. First, we did not assess reasons for loss of appetite or declining DI, such as nausea, taste, food preference, pain control, and dysgeusia. Second, we could not consider the intake of individual snacks because we could not keep track of them

completely. Except in special cases, the dietary needs of every patient were managed solely with food provided by the hospital; nevertheless, it is possible that DI may not be entirely accurate. Third, we did not assess postoperative muscle wasting and the prevalence of sarcopenia. Finally, the follow-up period in this study was only the duration of the hospital stay. Thus, there remain unanswered questions related to the long-term effects of postoperative DI.

Conclusion

This study investigated the effects of preoperative sarcopenia and postoperative DI on postoperative functional recovery after cardiac surgery. More than 30% of the subjects did not meet total energy requirements for DI after cardiac surgery. After adjustment for other confounding factors, both preoperative nutritional status and postoperative DI were independently associated with functional recovery, but preoperative sarcopenia was not. Regardless of age, sex, and the presence or absence of sarcopenia, aggressive nutritional intervention before surgery and/or during the early stage after surgery will help to improve functional recovery. There is a need for further studies to investigate the clinical effects of postoperative DI on long-term outcomes and prognosis in the future.

Conflicts of interest

The authors have declared that no competing interests exist.

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