〈Regular Article〉

Significance of Preoperative Body Composition Assessment on the Short-term Outcomes of Elective Cardiac Surgery

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ABSTRACT **Background**: Traditionally, surgical risk is determined by a preoperative assessment of age, comorbidities, and performance status. Although it is known that various age associated factors affect postoperative outcomes in the elderly, evidence in the field of cardiac surgery is still insufficient. In patients aged 50+ admitted to our hospital for elective cardiac surgery, body composition was evaluated immediately before surgery and its association with length of Intensive Care Unit (ICU) stay, length of hospital stay, and outcome was examined.

Methods: In 101 consecutive patients (52 with valvular disease, 24 with ischemic heart disease, 12 with arrhythmia, 11 with aortic aneurysm, and 2 with cardiac tumor) bioelectrical impedance analysis body composition measurements were taken on the day of surgery, and skeletal muscle mass index (SMI), the ratio of visceral fat area to skeletal muscle mass (VFA/SMM), and Phase Angle (PA) were measured and calculated.

Results: The subjects' age was 72.0 ± 8.8 years, body mass index (BMI) was 22.3 ± 3.9 kg/m^2, the length of hospital stay was 35.6 ± 28.0 days, and the ICU stay was 4.1 ± 3.1 days. The outcomes were 81 patients (80.2%) discharged to their home, 16 (15.8%) transferred to other hospitals, and 4 (4.0%) died.

A low SMI was associated with a longer hospital stay ($p < 0.01$), a high VFA/SMM was associated with transfer to another hospital or death ($p < 0.05$), and a PA <4.5 in men and <4.0 in women was associated with a longer hospital stay ($p < 0.05$).

Conclusion: Low skeletal muscle mass, a high visceral fat area to skeletal muscle mass ratio, and poor muscle quality were all associated with a worse short-term prognosis in patients undergoing elective cardiac surgery.

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Key words：Cardiac Surgery, Visceral fat, Muscle mass, Muscle quality, Prognosis

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INTRODUCTION

Japan has one of the world's longest life expectancies, but at the same time it has a declining birthrate and an aging population. By 2019, over 28% of the population was over 65 years old and some estimates suggest that by 2030 the population over 75 years old will exceed 20%.

As the number of elderly people whose diseases are cured or managed has increased due to remarkable progress in organ-specific medicine, the amount of elderly people with functional disabilities that were not apparent in the past has also increased. Among these, frailty[1] and sarcopenia[2] are gaining attention as factors that hinder healthy longevity. Since their onset and development lead to a shorter life expectancy and a decline in activities of daily living, there is a growing awareness of the importance of early detection and intervention.

Additionally, the surgical population is also aging. Although the incidence of postoperative complications is decreasing with advances in surgical techniques, it is also known that complications that occur more frequently in the elderly, such as postoperative delirium, can significantly affect life outcomes[3]. Various factors associated with aging, such as age, comorbidities, and performance status, are well known to be related to postoperative prognosis, but functional impairments in the elderly, such as cognitive dysfunction and sarcopenia, have also been reported to affect postoperative outcomes[4, 5]. Therefore, in addition to conventional preoperative evaluations, evaluating the degree of functional disability is attracting increased attention.

Bioelectrical impedance analysis (BIA) can noninvasively measure body composition (water, muscle mass, and fat mass) and currently has a reputation as a safe and useful technique for assessing sarcopenia, which is essentially an age-related loss of muscle mass[6]. A meta-analysis of gastrointestinal cancer patients showed iliopsoas muscle mass loss, as measured by abdominal computed tomography (CT), to be a factor negatively affecting the postoperative prognosis[7].

Conversely, it is known that an increase in relative body fat mass also has an impact on disease states, and it has been shown that both normal weight obesity and sarcopenic obesity have an impact on prognosis. The visceral fat area (VFA) to skeletal muscle mass (SMM) ratio is one indicator used to determine the degree of obesity. A study of patients undergoing a pancreaticoduodenectomy for pancreatic cancer reported that the VFA/SMM ratio was a strong predictor of postoperative complications[8].

In addition to muscle mass and muscle strength, the significance of assessing muscle quality has been becoming more apparent. Phase Angle (PA), which is calculated directly from BIA measurements without any estimation in the equation, is thought to reflect the physiological functional level of cells, and its efficacy as a nutritional and prognostic indicator has been gaining awareness. In a study on the association of PA with the short- and long-term prognosis in patients with gastrointestinal or liver cancer, a low PA was correlated with longer ICU stays, more hospitalizations and a worse 5-year survival rate[9].

Although the usefulness of such skeletal muscle quantity and quality evaluations has been demonstrated in both cancer patients and in geriatrics, there are still few reports in the field of cardiovascular surgery and few studies on the significance of either VFA/SMM ratio and PA.

We evaluated the relationship between those body composition parameters and the length of ICU stay, the length of hospital stay, and the outcome of being transferred to another hospital or death.

METHODS

The subjects were 101 consecutive patients aged 50 years or older who were admitted to Kawasaki

Medical School General Medical Center for elective cardiac surgery between February 2018 and April 2021. These included 42 cases of valvular disease, 8 cases of aortic aneurysm, 19 cases of ischemic heart disease, 2 cases of cardiac tumor, and 11 cases of arrhythmia. The reason why the subjects aged 50 years or older were enrolled is that It is known that sarcopenia occurs in patients with cardiovascular disease earlier than in those without.

The exclusion criteria were as follows: (1) an inability to walk independently; (2) stroke presenting with severe hemiplegia; (3) Parkinson's disease or syndrome; (4) having an artificial pacemaker, poor vision or blindness, and/or orthopedic surgery history; (5) marked cognitive function decline that makes communication difficult; and (6) refusal to consent to participate in this study or if any essential data was missing.

Hypertension was defined as taking antihypertensive treatments or a reported diagnosis of hypertension before admission. Diabetes was defined as taking antidiabetic treatments including insulin or a reported diagnosis of diabetes before admission.

Bioelectrical impedance analysis is a technology that sends a weak electric current through the body to calculate electrical impedance, which in turn measures body composition. We obtained eight-polar BIA measurements using an InBody S10 body composition analyzer (InBody Japan, Tokyo, Japan) with multiple frequency settings (1, 5, 50, 250, 500 and 1,000 kHz). The baseline (preoperative) data were measured in the supine position soon after anesthetic induction in the operating room.

The InBody S10 was used to measure the skeletal muscle mass index (SMI), total SMM, VFA, and PA. The SMI was calculated by dividing the limb skeletal muscle mass by the square of the height. The VFA/SMM was calculated by dividing VFA by SMM. PA is the arctangent value of the directly measured ratio of reactance to resistance, does not depend on conventional regression equations of body composition, and has been reported as a prognostic marker of disease severity and physical frailty[10, 11].

Low SMI was defined according to the Asian Working Group for Sarcopenia (AWGS) criteria of < 7.0 kg/m^2 in males, and < 5.7 kg/m^2 in females. A high VFA/SMM ratio was defined as the values in the highest quartile. Low PA was defined as <4.4 in males and < 4.0 in females, as previously reported[9].

The length of ICU stay, length of hospital stay, and outcome (transfer to another hospital or death) were calculated or extracted based on medical record entries. All the participants provided written informed consent for participation in the study. This study was approved by the institutional ethics board of Kawasaki Medical School (No.3651-03) and was conducted in accordance with the Declaration of Helsinki and its later amendments.

STATISTICAL ANALYSIS

Linear regression analyses between the baseline BIA data, including SMI, VFA/SMM, PA, and the parameters, namely ICU stay and duration of hospitalization, were conducted to identify correlations classified by gender.

The relationship between the baseline BIA data and short-term outcomes including in-hospital death or transfer to other hospitals was analyzed using an unpaired t-test. Additionally, multiple linear regression analyses were conducted with the ICU stay, duration of hospitalization and short-term outcomes as the dependent variables, with low SMI, high VFA/SMM and low PA as the independent variables, and with age, gender, body mass index (BMI), hemoglobin and serum albumin level as the adjusted variables.

Statistical analyses were performed using the JMP Pro 15 software (SAS Institute Inc., Cary, NC, USA). Statistical significance was set at a two-tailed $p < 0.05$.

RESULTS

The subjects' average age was 72.0 ± 8.8 years, BMI was 22.3 ± 3.9 kg/m^2. 91.1% had hypertension and 30.7% had diabetes mellitus. The median postoperative ICU stay was 3 days, and median hospital stay was 28 days. Postoperative outcomes were 81 patients (80.2%) discharged to their home, 16 patients (15.8%) transferred to other hospitals, and 4 patients (4.0%) died (Table 1). Regarding the four patients that died, the first case did not respond to long-term treatment for a post-operative infection and died on day 115; the second case developed a cerebral edema, which did not improve and died on day 21; the third case had worsening chronic obstructive pulmonary disease and died on day 133 due to cardiopulmonary arrest; the fourth case died on day 34 due to ongoing malignant pleural effusion from a thymic carcinoma whose liver metastases were only discovered postoperatively. Of the 16 transferred cases, 14 were transferred for continued rehabilitation to improve nutrition or physical impairment, and two were transferred for continued treatment for infectious diseases. Since the number of deaths was small, deaths and transfers were combined as a poor prognosis group, with the aim of examining whether preoperative body composition was related to either outcome in this study. SMI was 7.30 ± 1.30 kg/m^2 for men and 5.83 ± 1.48 kg/m^2 for women, with mean values above the AWGS 2019 criteria for sarcopenia in men and women.

Next, the association of SMI, VFA/SMM ratio, and PA with the length of ICU stay, length of hospital stay, and death or transfer was examined by gender. In males, there were negative correlations between SMI and the length of hospital stay (R^2 = 0.10, p = 0.015), PA and the length of ICU stay (R^2 = 0.10, p = 0.016), and also PA and the length of hospital stay (R^2 = 0.09, p = 0.021). The VFA/SMM ratio was positively correlated with the length of ICU stay (R^2 = 0.17, p = 0.001) and the length of hospital stay (R^2 = 0.28, p < 0.001). The VFA/SMM ratio and PA were both significantly associated with death or hospital transfer (p < 0.001, p = 0.007, respectively) (Fig. 1-a). Notably, none of the same

Table 1. Baseline Characteristics

	All (n = 101)	Male (n = 57)	Female (n = 44)
Age	72.0 ± 8.8	70.5 ± 8.7	73.9 ± 8.6
BMI, kg/m^2	22.3 ± 3.9	23.0 ± 3.9	21.3 ± 3.6
Hypertension, n (%)	92 (91.1)	53 (93.0)	39 (88.6)
Diabetes, n (%)	31 (30.7)	23 (40.4)	8 (18.2)
ICU stay, days*	3 (2 - 20)	3 (1 - 20)	3 (1 - 11)
Hospital stay, days*	28 (10 - 162)	27 (11 - 162)	29 (10 -117)
Death or transfer (%)	20 (19.8)	7 (12.3)	13 (29.5)
BNP, pg/mL	371.3 ± 741.7	283.2 ± 380.4	487.2 ± 1,038.1
eGFR, mL/min/1.73m^2	56.2 ± 24.5	56.2 ± 23.9	56.2 ± 25.5
Albumin, g/dL	3.97 ± 0.54	4.02 ± 0.50	3.92 ± 0.58
Hemoglobin, g/dL	13.1 ± 2.0	13.7 ± 2.2	12.2 ± 1.6
SMI, kg/m^2	6.66 ± 1.56	7.30 ± 1.30	5.83 ± 1.48
VFA, cm^2	75.6 ± 40.4	74.1 ± 42.1	77.5 ± 38.6
VFA/SMM	3.63 ± 2.24	2.93 ± 1.69	4.53 ± 2.55
PA	5.38 ± 2.16	5.51 ± 1.82	5.21 ± 2.54

* median number of days (range)

Abbreviations: BMI: body mass index, ICU: intensive care unit, BNP: Brain natriuretic peptide, eGFR: estimated glomerular filtration rate, SMI: skeletal muscle mass index, VFA: visceral fat area, SMM: skeletal muscle mass, PA: phase angle

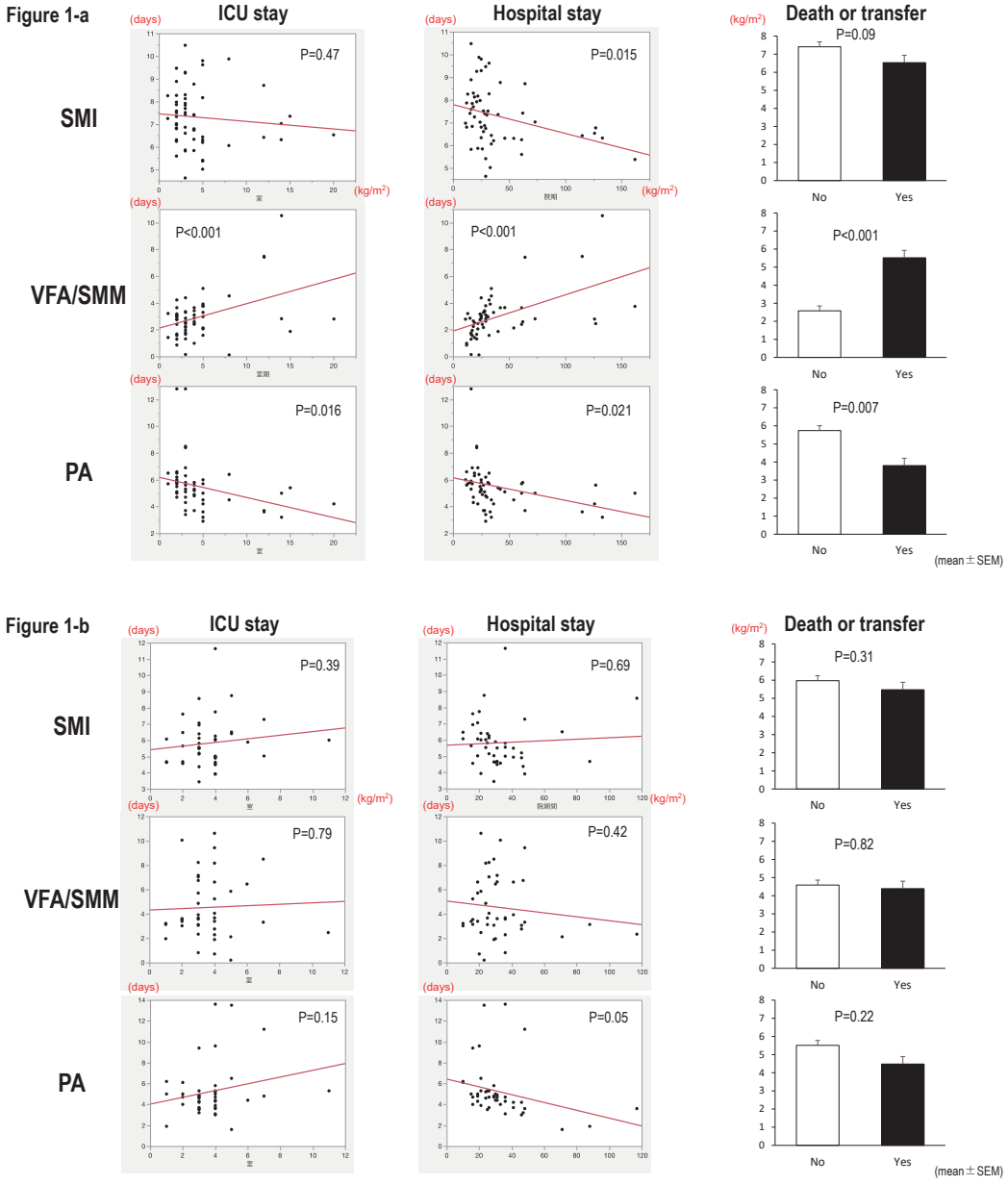

Fig. 1. The association of SMI, VFA/SMM ratio, and PA with the length of ICU stay, length of hospital stay, and death or transfer
Notes: a. Male, b. Female.
Abbreviations: ICU: intensive care unit, SMI: skeletal muscle mass index, VFA: visceral fat area, SMM: skeletal muscle mass, PA: phase angle.

associations were found in women (Fig. 1-b).

Multiple logistic regression analysis of the association of low SMI, a high VFA/SMM ratio, and low PA with the length of ICU stay, length of hospital stay, and death or hospital transfer revealed that a low SMI and a low PA were independently associated with the length of hospital stay (β = 0.338, p = 0.003 β = 0.264, p = 0.016), and a high

VFA/SMM ratio was independently associated with death or hospital transfer (OR = 3.24, 95% CI: 1.45-8.28, p = 0.003), as was a low serum albumin level (Table 2-a, b, c).

DISCUSSION

Organ function evaluation and risk assessment by performance status have traditionally been the standard for patients undergoing elective cardiovascular surgery. Few studies have examined whether the indices obtained from a preoperative body composition assessment, such as skeletal muscle mass, body fat mass, and muscle quality (PA), are associated with the length of hospital stay and short-term prognosis in patients undergoing elective cardiovascular surgery.

It has been reported that preoperative low body weight and anemia are associated with longer ICU stays[12, 13]. We also previously reported that a high extracellular fluid to intracellular fluid ratio, measured by BIA and called the edema index, is associated with longer ICU stays.14 This suggests that the duration of ICU stay may be significantly affected by changes in fluid volume which may not be associated with the other BIA measurements of SMI, the VFA/SMM ratio, and PA. On the other

Table 2. Multiple logistic regression analysis of the association of low SMI, a high VFA/SMM ratio, and low PA with the length of ICU stay, length of hospital stay, and death or hospital transfer

2-a) ICU stay

	β	95%CI	P value	β	95%CI	P value	β	95%CI	P value
Age	0.051	-0.053 - 0.089	0.616	0.016	-0.067 - 0.078	0.874	0.060	-0.049 - 0.092	0.550
Gender	-0.202	-10.39 - 1.076	0.053	-0.293	-1.609 - -0.228	0.010	-0.192	-1.246 - 0.043	0.067
BMI	0.285	-0.043 - 3.233	0.015	0.130	-0.066 - 0.275	0.227	0.214	0.015 - 0.327	0.032
Hemoglobin	-0.270	-5.847 - 0.762	0.029	-0.270	-0.779 - -0.046	0.028	-0.215	-0.720 - 0.061	0.097
Albumin	-0.117	-17.40 - 5.828	0.303	-0.131	-2.053 - 0.534	0.247	-0.086	-1.803 - 0.807	0.451
Low SMI	-0.136	-15.65 - -3.234	0.232						
High VFA/SMM				-0.204	-1.522 - 0.071	0.074			
Low PA							-0.152	-1.329 - 0.219	0.158

2-b) Hospital stay

	β	95% CI	P value	β	95% CI	P value	β	95% CI	P value
Age	0.089	-0.351 - 0.923	0.375	0.112	-0.318 - 1.034	0.296	0.117	-0.266 - 1.017	0.248
Gender	0.166	-10.39 - 1.076	0.110	-0.227	-12.80 - 0.057	0.052	-0.157	-10.28 - 1.447	0.664
BMI	0.222	-0.043 - 3.233	0.056	0.004	-1.577 - 1.639	0.969	0.043	-1.106 - 1.727	0.138
Hemoglobin	-0.185	-5.847 - 0.762	0.130	-0.194	-6.115 - 0.795	0.130	-0.094	-4.849 - 2.258	0.471
Albumin	-0.111	-17.40 - 5.828	0.325	-0.099	-17.41 - 7.027	0.401	-0.049	-14.46 - 9.294	0.667
Low SMI	0.338	-15.65 - -3.234	0.003						
High VFA/SMM				-0.088	-10.33 - 4.661	0.454			
Low PA							-0.264	-15.72 - -1.634	0.016

2-c) Death or transfer

	Odds ratio	95% CI	P value	Odds ratio	95% CI	P value	Odds ratio	95% CI	P value
Age	0.97	0.90 - 1.04	0.396	0.99	0.91 - 1.08	0.876	0.95	0.88 - 1.02	0.184
Gender	0.53	0.26 - 1.05	0.068	0.76	0.35 - 1.66	0.509	0.56	0.28 - 1.06	0.085
BMI	0.86	0.71 - 1.04	0.120	1.02	0.84 - 1.26	0.813	0.93	0.78 - 1.09	0.351
Hemoglobin	1.33	0.87 - 2.03	0.185	1.48	0.92 - 2.49	0.106	1.25	0.81 - 1.98	0.317
Albumin	10.44	2.48 - 43.87	0.001	14.48	3.48 - 82.93	< 0.001	8.84	2.35 - 43.79	0.003
Low SMI	1.84	0.84 - 4.03	0.125						
High VFA/SMM				3.24	1.45 – 8.28	0.003			
Low PA							1.33	0.67 - 2.61	0.407

Abbreviations: ICU: intensive care unit, BMI: body mass index, SMI: skeletal muscle mass index, VFA: visceral fat area, SMM: skeletal muscle mass, PA: phase angle

hand, in a study of 168 cardiac surgery cases (66.1% male), a low Phase Angle was associated with a longer ICU stay, and a low PA measured for 7 consecutive postoperative days was associated with a higher fluid balance and a longer cardiopulmonary bypass use time[15]. Another recent report revealed that the combination of low preoperative PA and grip strength was significantly associated with a prolonged ICU stay and all-cause mortality[16]. Furthermore, the present study also showed a negative correlation between PA and the length of ICU stay in males, which suggests that future studies focusing exclusively on male cases are warranted.

In the present study, a low SMI and a low PA were associated with the length of hospital stay. In a study of 192 cardiac surgical cases, preoperatively assessed sarcopenia was a risk factor for a prolonged hospital stay[17]. A report examining the association between preoperative PA and postoperative outcomes in 342 low-risk cardiac surgical patients found that low PA on the day before surgery was an independent risk factor for postoperative mortality and was associated with prolonged hospital stays[10]. The significant low PA results of this study seem to support those previous reports, suggesting that preoperative low muscle mass and poor muscle quality may be useful biomarkers to predict a prolonged hospital stay.

The length of ICU and hospital stays is influenced by several factors, not only physical or psychological factors, but also social factors. The general beds at our hospital are rarely full and patients are transferred to general beds as soon as it is determined that ICU management is no longer necessary. Moreover, as described in the result section, most transfers were for continued rehabilitation, and the rationale for discharge to a patient's home is largely based on the patient's physical and/or psychological improvement. Therefore, it is fair to say that ICU stay and hospital stay mostly reflects the physical or psychological conditions of the participants.

On the other hand, since some reports have shown that postoperative loss of skeletal muscle mass is associated with increased postoperative complications and a decreased quality of life[18], it is necessary to examine the relationship between pre- and postoperative changes in SMI and PA with the length of hospital stay and postoperative complications. Therefore, in a future study, we would like to gather a larger number of patients and examine the relationship between low preoperative SMI and postoperative complications, including postoperative delirium.

Low preoperative serum albumin has been shown to be associated with postoperative complications and worse postoperative prognosis in a number of studies, including a study of cardiovascular surgery patients over 75 years of age[19], and a study of 2180 heart bypass surgery patients[20]. Additionally, a high VFA/SMM ratio has been reported to be a risk factor for physical dysfunction and cardiovascular and metabolic diseases[21]. Sarcopenic obesity, defined as high visceral fat and low skeletal muscle mass, as measured by BIA before 325 cardiac surgeries, was associated with the occurrence of postoperative adverse events[22]. In another study which supports our findings, sarcopenic obesity, defined there as high visceral fat area with low iliopsoas muscle area, was measured by CT before 664 cardiac surgeries and was associated with postoperative muscle weakness and mortality[23]. Our results suggest that indices related to sarcopenic obesity are important not only to measure the risk of developing cardiovascular disease but also in prognosis after cardiac surgery.

Although we were able to demonstrate an association between skeletal muscle loss, sarcopenic obesity, and muscle quality with the length of hospital stay and the short-term prognosis in a variety of cardiac surgical cases, this study had

several limitations.

First, the diseases that were operated on were varied, with about half of the cases being valvular cases and about one-fourth being ischemic heart disease. Although it would be desirable to classify the patients into at least three groups for analysis based on their diseases, the current number of cases is not sufficient to withstand analysis, and we would like to further increase the number of cases used in future analyses.

Second, a previous report showed a relationship between postoperative complications and preoperative body composition indices, but in this study, detailed data on postoperative complications were not available and could not be analyzed. In future studies, we would like to collect and analyze data on postoperative delirium and other complications.

Third, this study does not have baseline data on nutritional status and exercise habits. The indicators such as SMI, VFA/SMM, and PA are known to be influenced by nutritional status and exercise habits in previous reports. Although preoperative serum albumin level was assessed as a proxy for nutritional status in this study, the mean value of 3.92 mg/dL was not low, and it is thought that most of the subjects enrolled in this study are not undernutrition. In addition, In the multiple logistic regression analysis adopting serum albumin level as a confounding factor, the VFA/SMM or PA was associated with hospital stay or death/transfer at least independently of serum albumin level (Table 2). This indicates that muscle mass and muscle quality might be a risk for prolonged hospital stay and post-discharge mortality, regardless of nutritional status.

On a positive note, it is important to emphasize that in this study the body composition data was obtained by the anesthesiology department immediately prior to surgery. In previous reports, the timing of body composition data acquisition was not consistent, ranging from one day to two weeks before surgery, and there is a possibility that the environment and stress in which a patient is placed may affect the body composition data. In this study, however, body composition data were obtained under preoperative anesthesia, the environment was constant, and the patient's circulation was stable. This is valuable not only because measurement bias is reduced, but also because it can be performed routinely.

Finally, in this study, the association between body composition data and short-term prognosis was more pronounced in men than in women. Skeletal muscle mass declines in both men and women after middle age, but the decline is greater in men[24], and the contribution of sarcopenia to accidental falls is greater in men than in women[25]. In addition, a recent report showed that in both men and women a higher muscle mass was associated with lower cardiovascular mortality, but high fat in women, regardless of muscle mass level, was associated with a lower cardiovascular mortality[26]. Indeed, the current data also showed that the VFA/SMM was positively associated with the length of ICU and hospital stay, suggesting that high body fat and low muscle mass may lead to adverse events in men, whereas this relationship was not observed in women. Those association listed above may be the reason for the gender difference observed in this study, but with few reports examining the phenomenon at present, future research is warranted.

CONCLUSION

The results suggest that low preoperative skeletal muscle mass, a high visceral fat area to skeletal muscle mass ratio, and poor muscle quality in patients undergoing elective cardiac surgery affect the short-term prognosis, especially in men.

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CONFLICTS OF INTEREST

None of the authors have any conflicts of interest to disclose.

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ABBREVIATIONS

ICU: intensive care unit

SMI: skeletal muscle mass index

VFA: visceral fat area

SMM: skeletal muscle mass

PA: phase angle

BMI: body mass index

BIA: bioelectrical impedance analysis

CT: computed tomography

AWGS: Asian Working Group for Sarcopenia