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ORIGINAL ARTICLE

Preoperative frailty is associated with progression of postoperative cardiac rehabilitation in patients undergoing cardiovascular surgery

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Abstract

Objective Preoperative frailty affects the progression of cardiac rehabilitation (CR) after cardiovascular surgery. Different frailty assessment measures are available. However, it remains unclear which tool most likely predicts the progress of CR. Our aim was to evaluate preoperative frailty using different methods and to identify the predictors in the progress of postoperative CR.

Methods Eighty-nine patients underwent elective cardiovascular surgery at our institution between May 2016 and April 2018. Mortality cases and patients without evaluation of preoperative frailty were excluded. This study included the remaining 78 patients. We divided the patients into two groups: 47 patients who achieved 100 m walking within 7 days after surgery (successful CR group) and 31 patients who achieved 100 m walking later than 8 days after surgery (delayed CR group). Preoperative frailty was assessed using the Kaigo-Yobo Check-List, Cardiovascular Health Study, Short Physical Performance Battery, and Clinical Frailty Scale.

Results The prevalence of frailty defined by these four measures was higher in the delayed CR group. The delayed CR group had lower nutritional status, serum hemoglobin level, serum albumin level, and psoas muscle index. Multivariable analysis demonstrated the Kaigo-Yobo Check-List score as an independent predictor for delayed CR (odds ratio 1.53, 95% confidence interval 1.18–1.98, $p=0.001$) and Clinical Frailty Scale as an independent predictor for discharge to a health care facility (odds ratio 3.70, 95% confidence interval 1.30–10.51, $p=0.014$).

Conclusions Among the various tools for assessing frailty, the Kaigo-Yobo Check-List was most likely to predict the progress of postoperative CR after elective cardiovascular surgery.

Keywords Frailty · Kaigo-Yobo Check-List · Cardiovascular surgery · Cardiac rehabilitation · 100 m walking

Introduction

Frailty is a geriatric syndrome reflecting increased vulnerability to stressors due to impairments in multiple physiologic systems. In the aging society, frailty has been a growing issue in patients undergoing surgery. Reportedly, frailty is a risk for postoperative complications and an independent predictor of in-hospital mortality, discharge to an institution, and decreased mid-term survival rate after cardiovascular surgery [1].

Frailty comprises of various clinical phenotypes involving nutritional status, physical function, exhaustion, wasting, and inactivity. Preoperative malnutrition has been shown to be associated with increased morbidity, lower survival rate, prolonged hospital stay, and delayed cardiac rehabilitation (CR) progression after cardiovascular surgery [2, 3]. Ogawa et al. showed that preoperative nutritional status was associated with the number of days to achieve independent walking after cardiac surgery [4]. In connection to frailty, sarcopenia is the age-associated decline in skeletal muscle mass and function, which represents a powerful predictor of mortality in the aging population [5, 6]. Among the several methods that evaluate sarcopenia, the psoas muscle area (PMA) is an objective and validated measure of muscle mass, which is measured using computed tomography (CT) [7]. Sarcopenia based on PMA is associated with higher mortality in various specialties, including trans-catheter aortic valve implantation (TAVI) [8].

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However, the impact of preoperative frailty on the progress of postoperative CR remains unclear. Furthermore, a variety of frailty assessment tools are currently available, and it is difficult to determine which assessment tool should be used to predict the progress of postoperative CR. In this study, we aimed to assess preoperative frailty using several scales and identify the predictors for the progression of postoperative CR in patients undergoing cardiovascular surgery.

Methods

This was a retrospective study based on our institutional database. A total of 89 patients underwent elective cardiovascular surgery at our institution between May 2016 and April 2018. To evaluate the relationship between preoperative frailty and postoperative CR, two in-hospital mortality cases and nine patients who were not preoperatively evaluated for frailty were excluded (in-hospital mortality was 2.4% in this period). Thus, this study included the remaining 78 patients (44 males, 34 females, average age 71.7 ± 11.8 years).

The Japanese guideline for CR indicates that it is favorable to achieve 100 m walking within 7 days after surgery [9]. In order to identify the risk factors for the delayed progress of CR, we divided the patients into two groups based on the progress of CR: 47 patients who achieved 100 m walking day within 7 days after surgery (successful CR group) and 31 patients who achieved 100 m walking later than 8 days or were unable to achieve 100 m walking (delayed CR group). The Ethical Review Board of Nerima Hikarigaoka Hospital approved this study. All patients had previously given their permission for the use of their medical records for research purposes.

Data on all variables evaluated before surgery were extracted from electronic medical records. Age, sex, body mass index (BMI), Geriatric Nutritional Risk Index (GNRI) [10], co-morbidities, laboratory data, left ventricular ejection fraction (LVEF), preoperative co-morbidities, the psoas muscle area index (PMI, cm^2/m^2), and frailty status were measured before surgery.

GNRI was used to assess the preoperative nutritional status of the patients. GNRI was calculated as follows [10]:

$$\mathrm{GNRI} = 14.89 \times \text{preoperative serum albumin (g/dL)} + \left[41.7 \times \text{preoperative body weight (kg)/ideal body weight (kg)}\right],$$

*Calculation of ideal body weight:

male = [height (cm) − 100 − (height − 150)/4]

female = [height (cm) − 100 − (height − 150)/2.5].

PMA, which is a validated measure of sarcopenia, was measured at the level of the third lumbar vertebrae using the most recent preoperative CT scans done within 3 months prior to surgery. PMI was calculated by standardizing PMA for height (cm^2/m^2).

Frailty status was evaluated using three assessment scales including the Kaigo-Yobo Check-List [11], the Cardiovascular Health Study (CHS) [12], the Short Physical Performance Battery (SPPB) [13], and the Clinical Frailty Scale (CFS) [14]. These scales were measured the day before surgery. In accordance with the previous studies, the cut-off values of frailty in each scale were four points or more for the Kaigo-Yobo Check-List, three points or more for CHS, and 8 points or less for SPPB [11–13].

The postoperative rehabilitation program at our hospital was based on the Guidelines for Rehabilitation in Patients with Cardiovascular Disease [9]. Except for the critically ill patients, postoperative rehabilitation started from the day after the surgery. The CR program was appropriately designed and modified according to an individual's body functions and general condition. The patients with the following symptoms did not move to the next level of exercise training in this study: (1) chest pain, severe shortness of breath, severe fatigue (Borg scale of > 13), dizziness, lightheadedness, or leg pain; (2) cyanosis, facial pallor, or cold sweats; (3) tachypnea (> 30/min); (4) atrial fibrillation or an increase in the incidence of arrhythmias; (5) ischemic ECG changes; (6) excessive changes in blood pressure; (7) an increase in heart rate by > 30 beats per minute, or (8) a decrease in oxygen saturation to < 90%. The progress in CR including 100 m walking was assessed. We did not apply the rehabilitation discontinuation criteria based on days after surgery. We comprehensively evaluated the patient's overall condition and consulted with doctors to determine whether postoperative rehabilitation should be carried out or not.

The data in this study were expressed as mean ± standard deviation for continuous variables and as frequencies and percentages for categorical variables. Patient characteristics between groups were compared using the Fisher's exact test for categorical variables and the unpaired Student's *t* test for continuous variables. Acute kidney injury was defined based on the Kidney Disease Improving Global Outcomes (KDIGO) clinical practice guidelines, i.e. the increase in serum creatinine value by 0.3 mg/dL or higher from the preoperative value within 48 h after surgery [15]. Low cardiac output syndrome was defined as (1) requiring intra-aortic balloon pump/percutaneous cardiopulmonary support to be weaned from cardiopulmonary bypass and/or (2) the need for adrenaline or more than 5 μg/kg/min of dopamine or dobutamine after correction of electrolytes and preload in

the intensive care unit [16]. Multivariable logistic regression analysis with $p < 0.20$ for inclusion and $p > 0.25$ for exclusion from the models was performed using the stepwise method to identify the independent predictors of (1) delayed CR and (2) discharge to a health care facility. Preoperative and intra-operative variables with $p < 0.20$ in the univariate analysis were subjected to multivariable analysis. All statistical analyses were performed using SPSS software version 25 (IBM, New York, USA). A p value of < 0.05 was considered statistically significant.

Results

Preoperative patient characteristics per group are shown in Table 1. The patients in the delayed CR group had lower GNRI, serum albumin, and PMI than those in the successful CR group. Preoperative frailty status per group is shown in Table 1. The Kaigo-Yobo Check-List, CHS points and CFS were higher and the SPPB point was lower in the delayed CR group as compared to the successful CR group. The prevalence of frailty status as defined by the Kaigo-Yobo Check-List, CHS, and SPPB

Table 1 Preoperative patient characteristics and preoperative frailty assessment

Variable	Total ($n=78$)	Successful CR group ($n=47$)	Delayed CR group ($n=31$)	p value
Age, years	71.7 ± 11.8	69.8 ± 12.7	74.7 ± 9.8	0.076
Male, *n* (%)	44 (56)	27 (57)	17 (55)	1.000
Body mass index, kg/m^2	23.6 ± 4.4	23.4 ± 4.2	23.8 ± 4.7	0.701
Geriatric nutritional risk index	95.2 ± 9.1	97.3 ± 8.9	92.1 ± 8.5	0.011
Hypertension, *n* (%)	54 (69)	30 (64)	24 (77)	0.223
Diabetes, *n* (%)	25 (32)	14 (30)	11 (35)	0.627
Dyslipidemia, *n* (%)	30 (38)	19 (40)	11 (35)	0.813
Renal insufficiency, *n* (%)[a]	18 (23)	8 (17)	10 (32)	0.170
Old myocardial infarction, *n* (%)	18 (23)	12 (26)	6 (19)	0.592
Heart failure, *n* (%)	21 (27)	11 (23)	10 (32)	0.440
COPD, *n* (%)	13 (17)	7 (15)	6 (19)	0.758
History of stroke, *n* (%)	10 (13)	5 (11)	5 (16)	0.507
History of leg fracture, *n* (%)	9 (12)	5 (11)	4 (13)	1.000
Serum hemoglobin, g/dL	12.7 ± 2.0	13.1 ± 1.2	12.2 ± 2.0	0.079
Serum creatinine, mg/dL	1.41 ± 1.75	1.14 ± 1.21	1.82 ± 2.30	0.136
Serum albumin, g/dL	3.7 ± 0.6	3.9 ± 0.5	3.5 ± 0.5	0.004
Brain natriuretic peptide, pg/mL	338 ± 457	312 ± 398	379 ± 535	0.549
C-reactive protein, mg/dL	0.7 ± 1.0	0.5 ± 0.7	0.9 ± 1.3	0.138
Left ventricular ejection fraction, %	58.0 ± 16.0	59.0 ± 14.7	56.5 ± 18.0	0.499
Psoas muscle index, cm^2/m^2	4.63 ± 1.38	4.98 ± 1.40	4.26 ± 1.27	0.047
Kaigo-Yobo Check-List, point	3.2 ± 2.4	2.4 ± 1.7	4.5 ± 2.6	0.000
Frailty defined by Kaigo-Yobo Check-List, *n* (%)	33 (42)	14 (30)	19 (61)	0.010
Cardiovascular Health Study, point	1.7 ± 1.6	1.2 ± 1.2	2.4 ± 1.8	0.003
Frailty defined by CHS, *n* (%)	20 (26)	8 (17)	12 (39)	0.038
Short Physical Performance Battery, point	9.7 ± 3.2	10.3 ± 2.6	8.7 ± 3.8	0.044
Balance test, point	3.4 ± 1.1	3.6 ± 0.9	3.1 ± 1.2	0.051
Gait test, point	3.2 ± 1.3	3.5 ± 1.1	2.9 ± 1.5	0.072
Chair stand test, point	3.0 ± 1.4	3.2 ± 1.2	2.7 ± 1.5	0.112
Frailty defined by SPPB, *n* (%)	19 (24)	8 (17)	11 (35)	0.104
Clinical Frailty Scale	3.5 ± 0.9	3.3 ± 0.7	4.0 ± 0.8	< 0.001
Grip strength, kg	23.5 ± 9.1	24.6 ± 9.6	21.8 ± 8.3	0.176
Gait speed, m/s	0.97 ± 0.30	1.01 ± 0.29	0.90 ± 0.32	0.115

Values are number of patients (%) or mean ± SD

CR cardiac rehabilitation, *COPD* chronic obstructive pulmonary disease, *CHS* Cardiovascular Health Study, *SPPB* Short Physical Performance Battery

[a]Serum creatinine > 1.5 mg/dL

was higher in the delayed CR group. However, grip strength and gait speed were similar between the groups. As shown in Table 2, the type of surgery except for mitral valve replacement, cardiopulmonary bypass, and cross-clamp times did not differ between the groups.

The progress of CR and postoperative morbidities are shown in Table 3. Postoperative hospital and intensive care unit stays were significantly longer in the delayed CR group. Regarding the progress of CR, the start day of rehabilitation was similar. However, the duration to achieve sitting, standing, walking, and 100 m walking were longer in the delayed CR group than in the successful CR group. The percentage of patients who achieved 100 m walking was also lower in the delayed CR group. However, the rate of discharge to own home did not differ between the groups. As for morbidities, the delayed CR group had a higher incidence of prolonged ventilator use.

Multivariable analysis was performed to determine independent factors for (1) delayed CR and (2) discharge to a health care facility. The predictors of the delayed CR are

Table 2 Operative date

Variable	Total ($n=78$)	Successful CR group ($n=47$)	Delayed CR group ($n=31$)	p value
Surgical procedure				
CABG, *n* (%)	31 (40)	18 (38)	13 (42)	0.815
Valve surgery, *n* (%)	46 (59)	28 (60)	18 (58)	1.000
Aortic valve replacement, *n* (%)	27 (35)	17 (36)	10 (32)	0.636
Mitral valve replacement, *n* (%)	10 (13)	3 (6)	7 (23)	0.025
Mitral valve repair, *n* (%)	14 (18)	10 (21)	4 (13)	0.386
CABG + valvular procedure, *n* (%)	7 (9)	3 (6)	4 (13)	0.427
Aortic surgery, *n* (%)	9 (12)	4 (9)	5 (16)	0.471
Ascending aorta replacement, *n* (%)	6 (8)	3 (6)	3 (10)	0.677
Aortic arch replacement, *n* (%)	6 (8)	3 (6)	3 (10)	0.677
Other, *n* (%)	2 (3)	2 (4)	0 (0)	0.515
CPB time, min	165 ± 52	159 ± 52	175 ± 52	0.249
Cross-clamp time, min	117 ± 36	114 ± 33	122 ± 41	0.415

Values are number of patients (%) or mean ± SD

CR cardiac rehabilitation, *CABG* coronary artery bypass grafting, *CPB* cardiopulmonary bypass

Table 3 Progress of cardiac rehabilitation

Variable	Total ($n=78$)	Successful CR group ($n=47$)	Delayed CR group ($n=31$)	p value
Intensive care unit stay, day	4.3 ± 1.7	3.7 ± 1.2	5.3 ± 1.9	< 0.001
Postoperative hospital stay, day	20.5 ± 10.2	16.3 ± 6.2	26.8 ± 11.9	< 0.001
Progress of rehabilitation				
Rehabilitation start day, day	1.3 ± 1.0	1.2 ± 0.6	1.6 ± 1.4	0.136
Sitting start day, day	1.6 ± 1.2	1.3 ± 0.8	2.2 ± 1.6	0.007
Standing start day, day	2.8 ± 2.9	2.0 ± 1.3	4.1 ± 4.0	0.006
Walking start day, day	5.4 ± 4.7	4.0 ± 1.4	7.5 ± 6.8	0.001
100 m walking day, day	7.9 ± 4.6	5.9 ± 1.2	11.5 ± 5.5	< 0.001
Achievement of 100 m gait, *n* (%)	74 (95)	47 (100)	27 (87)	0.022
Discharge to own home, *n* (%)	69 (88)	43 (91)	26 (84)	0.471
Postoperative morbidity				
Stroke, *n* (%)	1 (1)	0 (0)	1 (3)	0.397
Ventilator usage time, min	2031 ± 2709	1439 ± 859	2928 ± 4039	0.052
Prolonged ventilator use > 48 h, *n* (%)	9 (12)	1 (2)	8 (26)	0.002
Acute kidney injury, n (%)	6 (8)	2 (4)	4 (13)	0.208
Low cardiac output syndrome, *n* (%)	7 (9)	2 (4)	5 (16)	0.107

Values are number of patients (%) or mean ± SD

CR cardiac rehabilitation

shown in Table 4. The Kaigo-Yobo Check-List score was found to be an independent predictor for delayed CR (odds ratio = 1.53, 95% confidence interval 1.18–1.98, $p = 0.001$). The predictors of discharge to a health care facility are shown in Table 5. Multivariable analysis revealed CFS as an independent predictor for delayed CR (odds ratio = 3.70, 95% confidence interval 1.30–10.51, $p = 0.014$).

Discussion

The principal finding in this study was that Kaigo-Yobo Check-List was independently associated with the delayed progression of CR after elective cardiovascular surgery among several of the frailty assessment tools. The prevalence of preoperative frailty and the incidence of postoperative prolonged ventilator use were higher in the delayed CR group than in the successful CR group.

Currently, various scales have been used for the assessment of frailty, which include CHS, Kihon Check-List [17] and gait speed, nutrition status, and SPPB. In general, there are two types of frailty assessment measures. One is a comprehensive frailty evaluation that incorporates several aspects of phenotypes. For example, CHS evaluated weight loss, grip strength, self-reported exhaustion, slowness, and low physical activity level to evaluate frailty. However, this type of assessment is cumbersome and time-consuming. The other is a single performance measure, such as gait speed and grip strength. The concern in using a single performance measure is that it is unclear whether a single index can represent the clinical impact of several phenotypes of frailty. No matter which scale is used, the assessment measure should

Table 4 Predictors of delayed cardiac rehabilitation

Variable	Univariate		Multivariable	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age, years	1.04 (0.99–1.09)	0.083	–	–
Male, *n* (%)	0.89 (0.36–2.24)	0.820	–	–
Body mass index, kg/m^2	1.02 (0.92–1.13)	0.697	–	–
Geriatric nutritional risk index	0.94 (0.89–0.99)	0.014	–	–
Hypertension, *n* (%)	1.94 (0.69–5.45)	0.207	–	–
Diabetes, *n* (%)	1.30 (0.49–3.40)	0.598	–	–
Dyslipidemia, *n* (%)	0.81 (0.32–2.07)	0.661	–	–
Renal insufficiency[a], *n* (%)	2.32 (0.80–6.77)	0.123	–	–
Old myocardial infarction, *n* (%)	0.70 (0.23–2.12)	0.527	–	–
Heart failure, *n* (%)	1.56 (0.57–4.29)	0.390	–	–
COPD, *n* (%)	1.37 (0.41–4.55)	0.606	–	–
Stroke, *n* (%)	1.61 (0.43–6.12)	0.481	–	–
Fracture of legs, *n* (%)	1.24 (0.31–5.05)	0.760	–	–
Serum hemoglobin, g/dL	0.81 (0.63–1.03)	0.083	–	–
Serum creatinine, mg/dL	1.26 (0.95–1.68)	0.113	–	–
Serum albumin, g/dL	0.28 (0.11–0.71)	0.007	0.44 (0.16–1.23)	0.118
Brain natriuretic peptide, pg/mL	1.00 (0.99–1.00)	0.545	–	–
C-reactive protein, mg/dL	1.48 (0.91–2.41)	0.118	1.49 (0.83–2.65)	0.179
Left ventricular ejection fraction, %	0.99 (0.96–1.02)	0.494	–	–
Psoas muscle index, cm^2/m^2	0.70 (0.49–1.02)	0.062	–	–
Kaigo-Yobo Check-List, point	1.56 (1.23–1.99)	< 0.001	1.53 (1.18–1.98)	0.001
Cardiovascular Health Study, point	1.67 (1.20–2.32)	0.002	–	–
Short Physical Performance Battery, point	0.85 (0.73–0.99)	0.037	–	–
Clinical Frailty Scale, point	3.11 (1.62–6.00)	0.001		
Coronary artery bypass grafting, *n* (%)	1.16 (0.46–2.93)	0.748	–	–
Valve surgery, *n* (%)	0.94 (0.37–2.36)	0.894	–	–
Aortic surgery, *n* (%)	2.07 (0.51–8.40)	0.310	–	–
CPB time, min	1.01 (0.99–1.02)	0.246	–	–
Cross-clamp time, min	1.01 (0.99–1.02)	0.409	–	–

[a]Serum creatinine > 1.5 mg/dL

OR odds ratio, *CI* confidence interval, *COPD* chronic obstructive pulmonary disease, *CPB* cardiopulmonary bypass

Table 5 Predictors of discharge to a health care facility

Variable	Univariate		Multivariable	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age, years	1.12 (1.01–1.24)	0.035	–	–
Male, *n* (%)	0.58 (0.14–2.35)	0.445	–	–
Body mass index, kg/m^2	1.04 (0.89–1.21)	0.656	–	–
Geriatric nutritional risk index	0.94 (0.87–1.01)	0.100	–	–
Hypertension, *n* (%)	1.64 (0.31–8.54)	0.558	–	–
Diabetes, *n* (%)	0.57 (0.11–2.97)	0.506	–	–
Dyslipidemia, *n* (%)	1.32 (0.33–5.38)	0.696	–	-
Renal insufficiency[a], *n* (%)	1.80 (0.40–8.06)	0.442	-	-
Old myocardial infarction, *n* (%)	–	0.998	–	–
Heart failure, *n* (%)	1.42 (0.32–6.26)	0.646	–	–
COPD, *n* (%)	2.95 (0.63–13.75)	0.168	–	–
Stroke, *n* (%)	0.83 (0.09–7.47)	0.871	–	–
Fracture of legs, *n* (%)	2.53 (0.44–14.64)	0.300	–	–
Serum hemoglobin, g/dL	0.83 (0.58–1.19)	0.310	–	–
Serum creatinine, mg/dL	1.27 (0.95–1.70)	0.102	–	–
Serum albumin, g/dL	0.39 (0.12–1.33)	0.134	–	–
Brain natriuretic peptide, pg/mL	1.00 (0.99–1.00)	0.909	–	–
C-reactive protein, mg/dL	1.22 (0.69–2.15)	0.491	–	–
Left ventricular ejection fraction, %	0.99 (0.95–1.03)	0.655	–	–
Psoas muscle index, cm^2/m^2	0.66 (0.35–1.22)	0.184	–	–
Kaigo-Yobo Check-List, point	1.37 (1.01–1.87)	0.044	–	–
Cardiovascular Health Study, point	1.34 (0.88–2.04)	0.172	–	–
Short Physical Performance Battery, point	0.80 (0.67–0.96)	0.019	–	–
Clinical Frailty Scale, point	3.91 (1.48–10.37)	0.006	3.70 (1.30–10.51)	0.014
Coronary artery bypass grafting, *n* (%)	2.07 (0.51–8.40)	0.310	–	–
Valve surgery, *n* (%)	0.16 (0.03–0.842)	0.030	0.27 (0.04–1.80)	0.176
Aortic surgery, *n* (%)	10.24 (2.07–50.67)	0.004	5.57 (0.73–42.38)	0.097
CPB time, min	1.02 (1.00–1.03)	0.055	–	–
Cross-clamp time, min	0.99 (0.97–1.02)	0.609	–	–

OR odds ratio, *CI* confidence interval, *COPD* chronic obstructive pulmonary disease, *CPB* cardiopulmonary bypass

[a]Serum creatinine > 1.5 mg/dL

be reproducible, easy to measure in clinical practice, and highly predictive for outcomes.

In this study, we evaluated frailty using four comprehensive assessment tools: Kaigo-Yobo Check-List, CHS, SPPB, and CFS. The Kaigo-Yobo Check-List is easy to use in a clinical setting and can be evaluated in a short time with a few questions (15 items). The Kaigo-Yobo Check-List comprises 15 easy-to-answer questions, which mainly focus on three components: being homebound, falling, and malnutrition [11]. Unlike the CHS advocated by Fried and colleagues [12], the Kaigo-Yobo Check-List consists of only question items and does not require evaluation of body functions such as walking speed. The three components included in the Kaigo-Yobo Check-List were shown to be correlated with five characteristics (shrinking, exhaustion, low activity, slowness, weakness) that Fried et al. proposed as a constitution of frailty [12, 18]. Kojima et al. showed that the frailty status quantified by the Kaigo-Yobo Check-List was shown to be a predictor in the newly certified long-term care insurance and/or mortality over 3 years [19]. CHS is a general method of evaluating physical frailty that is used worldwide. SPPB is a method that evaluates the more detailed physical functions as compared to CHS; therefore, it was adopted as a method of evaluating frailty in this study. CFS is a subjective evaluation method that does not require expert knowledge and is a useful index to easily evaluate the prognosis of the elderly [14, 20]. CFS has been widely used in the assessment of patients undergoing TAVI. Preoperative CFS is reportedly associated with the completion rate of postoperative CR [21].

In the recent years, the impact of sarcopenia on clinical outcomes has gained attention because sarcopenia overlaps

with the concept of frailty. In most papers, psoas muscle measurement has widely been used for defining sarcopenia [7, 8]. Lower PMA has been shown to be associated with mortality in various specialties, including TAVI [8]. Nutritional status defined by GNRI was also reported to be associated with delayed CR [4]. However, neither PMI nor GNRI was independently associated with CR progression in this study. These findings suggest that comprehensive assessment of frailty, rather than the impairment in one of clinical manifestations of frailty such as loss of muscle mass and malnutrition, might be more helpful in predicting the progress of CR.

The delayed CR group had a higher incidence of prolonged ventilator use than the successful CR group. Previous studies have reported that prolonged ventilator use after cardiac surgery is related to the number of days from surgery until achievement of independent gait [22] and hospital days [23]. As age increases and physical function declines, respiratory function declines [24, 25]. Frail patients have systemic vulnerability to stressors and respiratory muscle function can also be impaired, leading to longer dependence on the ventilator postoperatively.

Not surprisingly, postoperative hospital stay was longer in the delayed CR group than in the successful CR group. However, the rates of discharge to own home were similar between the two groups. These results suggest that postoperative rehabilitation enable patients to be discharged to their own homes, even in those with frailty and delayed progress of CR.

There are several advantages in the preoperative prediction of delayed CR patients. First, it helps steer therapy toward surgical, trans-catheter, or medical treatment. In the current era, various treatment options are available for cardiovascular diseases and providing optimal treatment to each patient is increasingly needed. By predicting the progress of postoperative CR, surgeons can have a more comprehensive assessment of their patient and provide valuable information for patient counseling. Second, patients with frailty, as defined by the Kaigo-Yobo Check-List, may be the optimal target population that can benefit from preoperative interventions that facilitate the progress of postoperative CR. Although evidence about the efficacy of preoperative intervention such as aggressive prehabilitation and nutritional supplementation is currently sparse, identification of frail patients can help find candidates for preoperative intervention. Miguelena et al. showed that quality of life can improve after cardiac surgery even in frail elderly patients [26].

Study limitations

There are several limitations to this study. First, this is a single-center study involving a small sample size. Second, patients in this study underwent various types of surgeries which can affect the recovery from surgery, although there was no difference in types of surgeries between groups. Third, the impact of the delayed progression of postoperative CR on the long-term outcomes is not clear. In this study, we only focused on the predictors of delayed acquisition of 100 m walking after surgery. It is important to compare the outcomes after discharge between the groups.

Conclusion

Preoperative Kaigo-Yobo Check-List was the independent predictor for the progression of postoperative CR in patients undergoing cardiovascular surgery. Preoperative frailty assessment using the Kaigo-Yobo Check-List may help identify patients who will benefit from interventions such as prehabilitation and nutritional supplementation.

Compliance with ethical standards

Conflict of interest The authors have declared that no conflict of interest exists.

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