


Decreased activities of daily living at discharge predict mortality and readmission in elderly patients after cardiac and aortic surgery

A retrospective cohort study

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Abstract

Recently, activities of daily living (ADL) were identified as a prognostic factor among elderly patients with heart disease; however, a specific association between ADL and prognosis after cardiac and aortic surgery is not well established. We aimed to clarify the impact of ADL capacity at discharge on prognosis in elderly patients after cardiac and aortic surgery.

This retrospective cohort study included 171 elderly patients who underwent open operation for cardiovascular disease in a single center (median age: 74 years; men: 70%). We used the Barthel Index (BI) as an indicator for ADL. Patients were classified into 2 groups according to the BI at discharge, indicating a high (BI \geq 85) or low (BI $<$ 85) ADL status. All-cause mortality and unplanned readmission events were observed after discharge.

Thirteen all-cause mortality and 44 all-cause unplanned readmission events occurred during the median follow-up of 365 days. Using Kaplan–Meier analysis, a low ADL status was determined to be significantly associated with all-cause mortality and unplanned readmission. In the multivariable Cox proportional hazard models, a low ADL status was an independent predictor of all-cause mortality and unplanned readmission after adjusting for age, sex, length of hospital stay, and other variables (including preoperative status, surgical parameter, and postoperative course).

A low ADL status at discharge predicted all-cause mortality and unplanned readmission in elderly patients after cardiac and aortic surgery. A comprehensive approach from the time of admission to postdischarge to improve ADL capacity in elderly patients undergoing cardiac and aortic surgery may improve patient outcomes.

Abbreviations: ADL = activities of daily living, APACHE II = Acute Physiologic And Chronic Health Evaluation II, BI = Barthel Index, BMI = body mass index, CCI = Charlson comorbidity index, CPB = cardiopulmonary bypass, eGFR = estimated glomerular filtration rate, GNRI = Geriatric Nutritional Risk Index, Hb = blood hemoglobin, ICU = intensive care unit, IQR = interquartile range, RBC = red blood cell, STROBE = Strengthening the Reporting of Observational Studies in Epidemiology.

Keywords: ADL disability, all-cause mortality, cardiovascular operation, elderly

1. Introduction

The number of options regarding operations for cardiovascular disease has increased remarkably in Japan over the last 30 years,^[1] with operative mortality rates reported to be below

10%^[2] as a result of improved procedures; however, almost 40% of patients experience mortality or unplanned readmission^[3] within 1 year after hospital discharge. Although surgical results have improved, it remains a serious social concern that many

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patients still experience mortality or unplanned readmission after cardiovascular surgery. Moreover, Japan has one of the most rapidly aging societies, with an increasing number of elderly patients undergoing cardiovascular surgery.^[4,5] Since the elderly exhibit more diverse clinical presentations (i.e., comorbidity, frailty) than younger patients, it is important to identify factors that could influence prognosis—such as mortality or unplanned readmission after hospital discharge—when they undergo cardiovascular surgery.

In previous studies, age,^[6,7] sex,^[6,7] comorbidities,^[6–8] history of stroke,^[8] preoperative renal function,^[7,9] left ventricular ejection fraction,^[7] preoperative frailty,^[10–12] nonelective surgery,^[13] surgery type,^[7,9,14] perioperative multiple blood transfusions,^[9] duration of postoperative mechanical ventilation,^[15] and postoperative length of stay^[8,14–16] were reported to be prognostic factors after cardiovascular surgery. Additionally, several studies have recently reported that activities of daily living (ADL) upon hospital discharge predicts mortality^[17–19] or unplanned readmission^[18] in elderly patients with heart disease; therefore, ADL has attracted attention as a predicting factor for prognosis. However, few studies have focused on elderly patients after cardiovascular surgery; therefore, factors associated with prognosis after hospital discharge in elderly patients who have undergone cardiovascular surgery have not been fully investigated. Furthermore, its association with ADL remains unclear.

Herein, we aimed to survey the association between ADL at discharge and prognosis after hospital discharge in elderly patients who have undergone cardiac and aortic surgery.

2. Methods

2.1. Design and setting

This retrospective cohort study was conducted at the Shinshu University Hospital in accordance with the Strengthening of Reporting of Observational Studies in Epidemiology (STROBE) Statement.^[20] In this acute phase hospital, elderly patients who underwent surgery for cardiovascular disease were provided with postoperative care and rehabilitation during hospitalization. Rehabilitation with full risk management and control was postoperatively provided to patients as early as possible by a multidisciplinary team (doctor, nurse, physiotherapist, occupational therapist, speech therapist, and clinical engineering technologist).

Postoperative rehabilitation consisted of the following interventions: early mobilization, pulmonary rehabilitation, delirium prevention, aerobic exercises, resistance training, ADL training, and patient education according to the Japanese Circulation Society's guidelines for rehabilitation of inpatients with cardiovascular disease.^[21]

2.2. Participants

All patients aged ≥ 65 years who underwent cardiac and aortic surgery via open procedure at the Shinshu University Hospital between January and December 2018 were included in the study. There were 204 consecutive patients who underwent cardiac and aortic surgery via open procedure during this period. Eleven patients with preoperative ADL dependence, 11 patients with in-hospital mortality, and 11 patients with incomplete ADL assessments were excluded from the study (Fig. 1). Patients underwent one of the following open procedures: coronary artery bypass, valvular surgery, surgical repair for the thoracic aorta, combined surgery, surgical repair for the abdominal aorta, or other procedures (2 patients underwent benign cardiac tumor resection, 1 patient underwent surgical ventricular restoration, and 1 patient underwent pulmonary thromboendarterectomy). Other procedures (i.e., minor vascular surgery, hemodialysis access surgery, and endovascular surgery) were not included in this study.

2.3. Characteristics of the participants

All data were retrieved from the Shinshu University Hospital electronic medical records, including preoperative status, surgical parameters, and postoperative courses. Preoperative variables included age, sex, body mass index (BMI), prior cardiovascular surgery (yes/no), history of stroke (yes/no), comorbidities, estimated glomerular filtration rate (eGFR), blood hemoglobin (Hb) concentration, nutritional status, and ejection fraction. Comorbidities were assessed using the Charlson comorbidity index (CCI),^[22] and nutritional status was assessed using the Geriatric Nutritional Risk Index (GNRI).^[23] We reviewed the data within 1 week before surgery. Variables for surgical parameters included type of operation (elective/urgent/emergent), type of procedure, operative time, cardiopulmonary bypass (CPB) time, cross-clamp time, amount of red blood cells (RBCs)

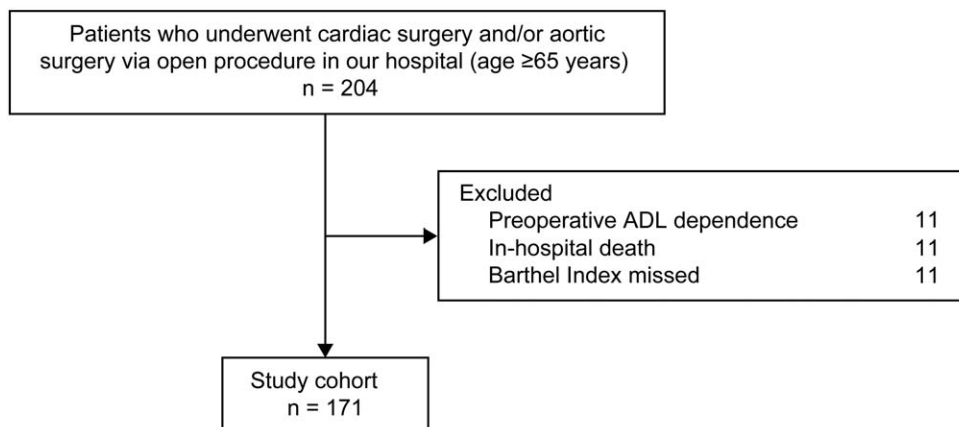


Figure 1. Flow diagram of the study. ADL=activities of daily living.

transfused, and Acute Physiologic And Chronic Health Evaluation II (APACHE II)^[24] score at intensive care unit (ICU) admission. Variables for the postoperative course included duration from surgery to extubation, duration from surgery to initial mobilization, incidence of postoperative delirium (yes/no), length of hospital stay, and discharge destination (home discharge or transfer to rehabilitation hospital). Initial mobilization was defined as level 2 (passive lift or slide transfer to the chair, with no standing or sitting on the edge of the bed) or level 3 (sitting over the edge of the bed) of the ICU mobility scale.^[25] Postoperative delirium was diagnosed by a clinician based on the Diagnostic Statistical Manual of Mental Disorders (fifth edition) criteria.

2.4. ADL assessment

We calculated the Barthel Index (BI)^[26] as an indicator for ADL. The BI score ranges from 0 to 100 (lower scores indicate greater disability) and classifies dependence across 10 basic ADLs: feeding, transferring from bed to chair, going to the toilet, bathing self, grooming, dressing, walking on a level surface, ascending and descending stairs, and controlling the bowel and bladder. The BI was used to assess the level of functional ability based on the ADL that reflects dependency needs in daily activities among the elderly.^[27] The cutoff value for functional independence was BI=85, as reported in several previous studies.^[17,28,29] In this study, patients were divided into low ADL status (BI < 85) or high ADL status (BI ≥ 85) according to BI at discharge.

2.5. Follow-up after discharge from our hospital

After postoperative care and medical treatment, patients with stable general conditions were discharged from our hospital. Patients whose level of physical and psychological function and ADL level did not recover to preadmission levels due to postoperative complications and/or disuse syndrome were considered for transfer to another hospital to continue rehabilitation and management of social support upon completion of postoperative care and medical treatment. In principle, both patient categories—those discharged home and those transferred to another hospital—would receive regular outpatient visits and medical examinations in our hospital after hospitalization. This study investigated all-cause mortality and unplanned readmission after discharge from our hospital; scheduled readmissions (for treatment or medical examination) were not included. The endpoint of follow-up was the incidence of all-cause mortality, or unplanned readmission or transfer as an outpatient to another hospital. The last follow-up date reviewed was November 30, 2020.

2.6. Statistical analysis

Normal distribution was observed using the Shapiro–Wilk test. Continuous variables are expressed as mean and standard deviation or median and interquartile range (IQR: 25th–75th percentile) depending on the results of the Shapiro–Wilk test; categorical variables are expressed as frequencies and percentages. Between-group comparisons of continuous variables were performed using the Student *t* test or Mann–Whitney *U* test, and the χ^2 test was used to compare categorical variables between groups. The time-to-event incidence of the clinical outcomes after

discharge from our hospital was determined using Kaplan–Meier analysis with the log-rank test, and Cox proportional hazard models were applied to determine independent predictors of all-cause mortality and unplanned readmission during follow-up periods after discharge from our hospital. Univariable analyses were used to examine associations between variables, and mortality and unplanned readmission. Multivariable analyses were used to estimate the independent prognostic effect of ADL level at discharge on all-cause mortality and unplanned readmission. We used a conventional *P* value of < .05 to determine the level of statistical significance. All analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp, Armonk, NY).

2.7. Ethics approval

This study was conducted in accordance with the Declaration of Helsinki^[30] and ethical guidelines for medical and health research involving human subjects.^[31] This study was approved by the Ethics Committee of the Shinshu University School of Medicine (Approval Number 4325). As this was a retrospective study, the Shinshu University Hospital Internet homepage published information about the study, allowing patients to withdraw from participation.

3. Results

The cohort consisted of 171 patients who underwent cardiovascular surgery and postoperative rehabilitation; patients' clinical characteristics are shown in Table 1. The median age was 74 years (IQR: 71–80), and 70% of the patients were men; the median preoperative CCI score was 2 (IQR: 1–3). A total of 20% of patients underwent emergent surgery; the most frequent surgery type was surgical repair of the thoracic aorta (34%), followed by valvular surgery (22%) and surgical repair of the abdominal aorta (21%). The median length of postoperative hospital stay was 17 days. The median BI at discharge was 100 (IQR: 90–100).

Among the 171 patients, 30 (18%) had a low ADL status, and 141 (82%) had a high ADL status. In comparing the preoperative status between the 2 ADL status groups, prior cardiovascular surgery and history of stroke were found to be more prevalent in the low ADL status (BI < 85) group than in the high ADL status (BI ≥ 85) group. Furthermore, eGFR, Hb, and GNRI were lower in the low ADL status group than in the high ADL status group. Comparing surgical parameters between the 2 groups, the number of emergent operations, operative time, CPB time, cross-clamp time, amount of RBCs transfused, and APACHE II score at ICU admission were found to be significantly higher in the low ADL status group. Conversely, the number of surgical repairs to the abdominal aorta was significantly lower in the low ADL status group. Comparing postoperative courses between groups, the duration from surgery to extubation, duration from surgery to initial mobilization, incidence of postoperative delirium, and length of hospital stay were significantly higher in the low ADL status group; in other words, the BI at discharge and frequency of home discharges were lower than in the high ADL status group.

During the follow-up period after discharge from our hospital (median: 365 days; IQR: 148–697 days), 13 patients experienced all-cause mortality, and 44 experienced all-cause unplanned readmissions. The most common reason for mortality and unplanned readmission was cardiovascular causes, followed by

Table 1
Characteristics stratified by Barthel Index score at discharge.

Variables	Total (n=171)	BI < 85 (n=30)	BI ≥ 85 (n=141)	P value
Preoperative status				
Age, yrs	74 (71–80)	78 (73–82)	74 (71–79)	.053*
Male, n (%)	120 (70)	18 (60)	102 (72)	.180†
BMI, kg/m ²	23.5 ± 3.4	23.2 ± 3.6	23.5 ± 3.4	.599‡
Prior cardiovascular surgery, n (%)	33 (19)	10 (33)	23 (16)	.032†
History of stroke, n (%)	46 (27)	16 (53)	30 (21)	<.001†
Comorbidities (CCI)	2 (1–3)	2 (1–3)	2 (1–3)	.418*
eGFR, mL/min/1.73 m ²	52.6 ± 20.6	39.5 ± 19.5	55.4 ± 19.8	<.001‡
Hemoglobin, g/dL	13.0 ± 2.1	12.1 ± 2.4	13.2 ± 1.9	.004‡
GNRI	102.6 ± 10.6	98.6 ± 11.8	103.4 ± 10.2	.024‡
Ejection fraction§	64.0 (57.0–73.3)	63.6 (54.5–72.0)	64.0 (57.3–74.0)	.675*
Surgical parameters				
Elective/Urgent/Emergent, n (%)	130 (76)/6 (4)/35 (20)	17 (57)/2 (6)/11 (37)	113 (80)/4 (3)/24 (17)	.024†
Type of procedures				
Coronary artery bypass, n (%)	11 (6)	2 (7)	9 (6)	.954†
Valvular, n (%)	37 (22)	6 (20)	31 (22)	.810†
Thoracic aorta, n (%)	58 (34)	14 (39)	44 (31)	.104†
Combined, n (%)	26 (15)	6 (20)	20 (14)	.421†
Others, n (%)	4 (2)	0 (0)	4 (3)	.351†
Abdominal aorta, n (%)	35 (21)	2 (7)	33 (23)	.039†
Operative time, min	365 (292–472)	453 (329–596)	359 (287–435)	.005*
CPB time, min	181 (0–248)	212 (175–338)	167 (0–239)	.003*
Cross-clamp time, min	98 (0–144)	123 (91–152)	89 (0–145)	.036*
RBC transfusion, unit	10 (4–16)	15 (12–21)	8 (4–14)	<.001*
APACHE II score at ICU admission	16 (13–20)	19 (16–24)	16 (13–19)	.001*
Postoperative course				
Days from surgery to extubation	1 (1–2)	2 (1–5)	1 (1–1)	<.001*
Days from surgery to initial mobilization, d	2 (1–3)	3 (2–6)	2 (1–2)	<.001*
Incidence of postoperative delirium, n (%)	49 (32)	21 (70)	35 (25)	<.001†
Length of hospital stay, days	17 (12–29)	32 (22–71)	16 (12–22)	<.001*
BI at discharge	100 (90–100)	65 (41–76)	100 (95–100)	<.001*
Home discharge, n (%)	127 (83)	6 (20)	132 (94)	<.001†

Data are expressed as mean ± standard deviation or median (interquartile range).

APACHE II=Acute Physiologic And Chronic Health Evaluation II, BI=Barthel Index, BMI=body mass index, CCI=Charlson comorbidity index, CPB=cardiopulmonary bypass, eGFR=estimated glomerular filtration rate, GNRI=Geriatric Nutritional Risk Index, ICU=intensive care unit, RBC=red blood cell.

* Mann–Whitney *U* test.

† Chi-squared test.

‡ Unpaired Student *t* test.

§ Ejection fraction (n=136): 35 patients had no data because of emergent operation.

infection. Kaplan–Meier analysis revealed that the incidence rates of all-cause mortality, all-cause unplanned readmission, and all-cause mortality or unplanned readmission after discharge from our hospital were significantly higher in the low ADL status (BI < 85 at discharge) group (Fig. 2).

The univariable Cox proportional hazards analysis showed that a BI < 85 at discharge, preoperative BMI, preoperative CCI, preoperative eGFR, preoperative Hb, operative time, CPB time, RBC transfusion, incidence of postoperative delirium, and length of postoperative hospital stay were related to all-cause mortality during the follow-up period (Table 2). Similarly, a BI < 85 at discharge, history of stroke, RBC transfusion, APACHE II score at ICU admission, days from surgery to extubation, days from surgery to initial mobilization, incidence of postoperative delirium, and length of postoperative hospital stay were related to all-cause unplanned readmission during the follow-up period (Table 2).

In the multivariable Cox proportional hazards analysis, a BI < 85 at discharge following adjustments for factors reported to be relevant in previous studies (age, sex, length of hospital stay), relevant preoperative variables (CCI, history of stroke, eGFR),

relevant surgical variables (emergent operation, operative time, CPB time, cross-clamp time, RBC transfusion, APACHE II score at ICU admission), and relevant postoperative course variables (days from surgery to extubation) predicted all-cause mortality or unplanned readmission (Table 3).

4. Discussion

In our study, patients with a low ADL status at discharge had a higher incidence of all-cause mortality and unplanned readmission within the follow-up period, compared with patients with a high ADL status. Additionally, a low ADL status at discharge predicted all-cause mortality and unplanned readmission after adjusting for the major confounders reported in previous studies, such as age, sex, comorbidity, history of stroke, eGFR, emergent operation, operative time, CPB time, cross-clamp time, RBC transfusion, APACHE II score at ICU admission, duration from surgery to extubation, and length of hospital stay.

Recently, the association between ADL and prognosis in patients with cardiac disease has been reported in several studies. Higuchi et al^[17] reported that ADL, as indicated by the BI,

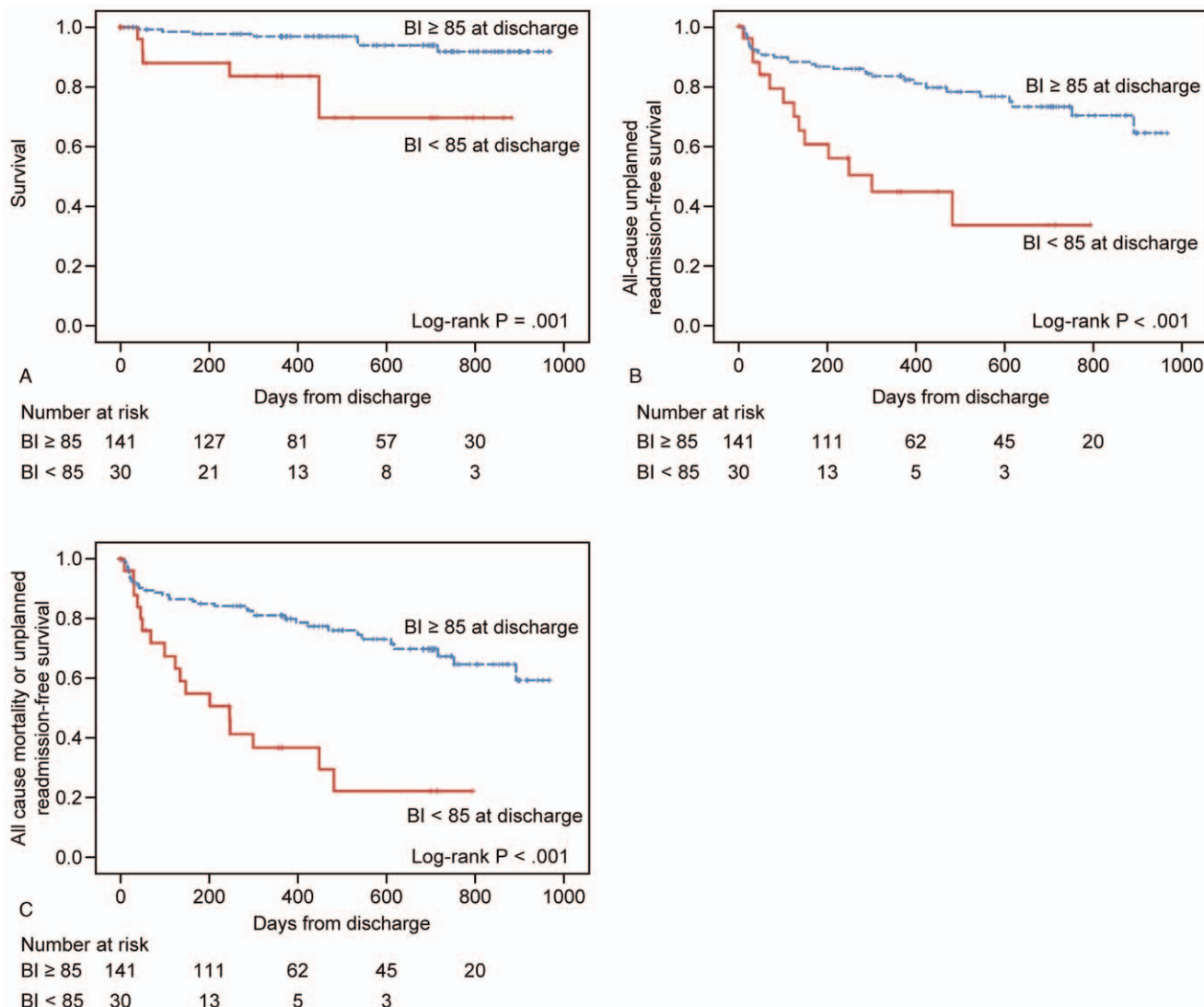


Figure 2. Kaplan–Meier survival curves comparing patients with a BI ≥ 85 and < 85. The survival rate (A), all-cause unplanned readmission-free survival rate (B), and all-cause mortality or unplanned readmission-free survival rate (C) were significantly lower in the BI < 85 at discharge group. The cutoff value of the BI at discharge to divide patients into 2 groups was determined to be 85, which has been reported as the value of functional dependency. BI=Barthel Index.

predicted mortality in very elderly patients (mean age: 88.2 ± 3.0 years) undergoing percutaneous coronary intervention. Similarly, Uemura et al^[18] reported that a low ADL status at discharge and decreased BI during hospitalization predicted all-cause mortality or readmission within 1 year after discharge in patients with acute heart failure. Motoki et al^[19] also reported that a low ADL status at discharge and poor improvement in ADL capacity during hospitalization predicted all-cause mortality after discharge in patients with acute decompensated heart failure; however, few previous studies have reported an association between ADL and prognosis in patients who underwent cardiovascular surgery. Marcassa et al^[7] reported the BI to be a major predictor of survival and hospitalization during a 5-year follow-up in patients admitted for inpatient cardiac rehabilitation after cardiac surgery (mean age: 68 ± 11 years; time from surgery to inpatient cardiac rehabilitation admission: 9.7 ± 11.2 days).

A decrease in ADL performance leads to a limited amount of physical activity in daily life.^[17,18] Lund et al^[32] reported that

limited physical activity leads to an increased mortality rate in patients who had undergone cardiac surgery, while Waring et al^[33] reported that the physical activity of patients with heart failure is associated with early readmission after discharge. It is known that limited physical activity is a risk factor for the onset or exacerbation of cardiovascular disease.^[34] In our study, the most common reasons for mortality and unplanned readmission were cardiovascular causes and limited physical activity—affected by a low ADL status—which may have influenced the occurrence of mortality and unplanned readmission. Additionally, a severe decrease in ADL performance leads to an increased risk of the patient becoming bedridden. Bedridden patients usually present with impaired function of various organs and an increased risk for progression of disuse syndrome, decubitus ulcer, and infections^[17]; therefore, patients with a low ADL status are more likely to experience mortality or unplanned readmission.

Comprehensive interventions to increase ADL capacity during the inpatient period and postdischarge are needed to

Table 2**Univariable Cox proportional hazards analysis for predictors of all-cause mortality and unplanned readmission.**

Univariable analysis	All-cause mortality			All-cause unplanned readmission		
	HR	95% CI	P value	HR	95% CI	P value
BI < 85 at discharge	5.518	1.849–16.470	.002	3.402	1.758–6.587	<.001
Age, yrs	1.018	0.929–1.116	.698	0.995	0.946–1.047	.849
Male sex	0.653	0.213–1.995	.454	0.684	0.369–1.266	.227
BMI	1.167	1.001–1.361	.049	1.082	0.990–1.183	.083
Prior cardiovascular surgery	2.492	0.814–7.631	.110	1.341	0.676–2.657	.401
History of stroke	1.881	0.614–5.765	.269	1.883	1.016–3.490	.044
CCI	1.363	1.022–1.818	.035	1.048	0.862–1.273	.638
eGFR, mL/min/1.73 m ²	0.973	0.948–0.998	.034	0.991	0.977–1.005	.189
Hemoglobin, g/dL	0.705	0.539–0.923	.011	0.977	0.843–1.133	.763
GNRI	0.982	0.930–1.037	.511	1.016	0.985–1.048	.307
Ejection fraction*	1.001	0.953–1.051	.982	1.000	0.971–1.029	.985
Emergent operation	1.309	0.360–4.763	.682	1.227	0.588–2.561	.585
Operative time, min	1.002	1.001–1.004	.008	1.001	0.999–1.002	.318
CPB time, min	1.006	1.001–1.010	.007	1.002	1.000–1.004	.109
Cross-clamp time, min	1.004	0.999–1.010	.126	1.003	1.000–1.006	.082
RBC transfusion, unit	1.071	1.044–1.098	<.001	1.027	1.005–1.050	.017
APACHE II score at ICU admission	1.066	0.993–1.145	.076	1.052	1.009–1.097	.018
Days from surgery to extubation	1.048	0.973–1.128	.218	1.059	1.017–1.103	.006
Days from surgery to initial mobilization	1.143	0.997–1.310	.056	1.132	1.034–1.239	.007
Incidence of postoperative delirium	5.476	1.683–17.823	.005	2.454	1.348–4.468	.003
LOHS	1.017	1.006–1.028	.002	1.009	1.002–1.017	.018

APACHE II=Acute Physiologic And Chronic Health Evaluation II, BI=Barthel Index, BMI: body mass index, CCI=Charlson comorbidity index, CI=confidence interval, CPB=cardiopulmonary bypass, eGFR=estimated glomerular filtration rate, GNRI=Geriatric Nutritional Risk Index, HR=hazard ratio, ICU=intensive care unit, LOHS=length of hospital stay, RBC=red blood cell.

*Ejection fraction (n=136): 35 patients had no data because of emergent operation.

prevent mortality and unplanned readmission after hospital discharge. Regarding inpatient interventions, there is a need to identify factors related to ADL status at discharge based on the patient's preoperative, perioperative, and postoperative course, as well as to implement multicomponent interventions for patients whose ADL capacity is expected to decline. Comparing the low versus high BI groups (BI ≥ 85 or BI < 85) at discharge in this study identified significant differences in preoperative patient attributes, such as prior cardiovascular surgery, history of stroke, eGFR, Hb, and GNRI; history of stroke, preoperative eGFR, and preoperative Hb were also found to influence the occurrence of mortality or unplanned readmission during the follow-up period. During the intraoperative and postoperative courses, variables related to the type of surgery (emergent

operation, open abdominal surgery, and open heart surgery), surgical invasion (operative time, CPB time, cross-clamp time, RBC transfusion, and APACHE II score at ICU admission), and postoperative complications (delayed extubation, delayed mobilization, and postoperative delirium) were associated with decreased ADL status at discharge and the occurrence of mortality or unplanned readmission during the follow-up period. It is, therefore, important to prevent the progression of postoperative disuse syndrome in patients with these risk factors. For patients with these risk factors, the implementation of preoperative rehabilitation (reported to be effective in a previous study)^[35] and mobilization from as early as possible after surgery to increase ADL status at discharge^[36] may improve patient prognosis.

Table 3**Association of Barthel Index at discharge with all-cause mortality or unplanned readmission.**

Multivariable model	HR	95% CI	P value
BI < 85 at discharge			
Adjusted for:			
Age, sex, LOHS, CCI	3.379	1.687–6.767	.001
Age, sex, LOHS, history of stroke	2.928	1.356–6.319	.006
Age, sex, LOHS, eGFR	3.322	1.628–6.779	.001
Age, sex, LOHS, emergent operation	3.432	1.667–7.067	.001
Age, sex, LOHS, operative time	3.255	1.618–6.549	.001
Age, sex, LOHS, CPB time	3.083	1.604–6.966	.001
Age, sex, LOHS, cross-clamp time	3.423	1.482–6.412	.003
Age, sex, LOHS, amount of RBC transfusion	2.821	1.376–5.781	.005
Age, sex, LOHS, APACHE II at ICU admission	3.222	1.607–6.459	.001
Age, sex, LOHS, days from surgery to extubation	2.981	1.450–6.130	.003

APACHE II=Acute Physiologic And Chronic Health Evaluation II, BI=Barthel Index, CCI=Charlson comorbidity index, CI=confidence interval, CPB=cardiopulmonary bypass, eGFR=estimated glomerular filtration rate, HR=hazard ratio, ICU=intensive care unit, LOHS=length of hospital stay, RBC=red blood cell.

Regarding postdischarge interventions, the continuation of outpatient cardiac rehabilitation may improve patient outcomes^[37]; however, the number of outpatient cardiac rehabilitation programs for patients after cardiovascular surgery is remarkably lower in Japan than in other developed countries.^[38,39] Continuing cardiac rehabilitation in the outpatient or community setting may contribute to the maintenance of ADL status and improved prognosis of patients with a low ADL status on hospital discharge.

4.1. Limitations

This study has several limitations; first, due to the single-center, retrospective nature of this study, the sample size was relatively small in terms of the number of mortality and unplanned readmission events encountered. To avoid over-fitting, we conducted several multivariable Cox proportional models to control for the effects of the confounding variables reported in previous studies. Second, our study population was heterogeneous, as we enrolled all types of open operations for cardiovascular disease. We analyzed operative time, CPB time, cross-clamp time, and RBC transfusion using a multivariable model to adjust for the prognostic impact of the different surgical types. Third, data on postoperative ADL status were limited to discharge records from our hospital only; we could not obtain data on changes in ADL status after discharge. Finally, the follow-up period was short in this study. Further, large, prospective cohort studies are needed to assess the impact of ADL status on outcomes in elderly patients after cardiovascular surgery.

5. Conclusion

The present study indicated that a low ADL status (indicated by a BI < 85) at discharge predicted all-cause mortality and unplanned readmission in elderly patients after cardiac and aortic surgery. The results of the present study may be a useful indicator for goal-setting in the postoperative care and rehabilitation of elderly patients who have undergone cardiac and aortic surgery, as well as in developing interventions after discharge from an acute care hospital.

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References

- Masuda M, Okumura M, Doki Y, et al. Committee for Scientific Affairs, The Japanese Association for Thoracic Surgery Thoracic and cardiovascular surgery in Japan during 2014: annual report by the Japanese Association for Thoracic Surgery. *Gen Thorac Cardiovasc Surg* 2016;64:665–97.
- Miyata H, Tomotaki A, Motomura N, Takamoto S. Operative mortality and complication risk model for all major cardiovascular operations in Japan. *Ann Thorac Surg* 2015;99:130–9.
- Jacobs JP, Alam SS, Owens SL, et al. The association between novel biomarkers and 1-year readmission or mortality after cardiac surgery. *Ann Thorac Surg* 2018;106:1122–8.
- Sumi M, Ariyoshi T, Miura T, et al. Are octogenarians in good condition after cardiac valvular surgery? *Ann Thorac Cardiovasc Surg* 2014;20:1021–5.
- Handa N, Miyata H, Motomura N, Nishina T, Takamoto S. Japan Adult Cardiovascular Database Organization Procedure- and age-specific risk stratification of single aortic valve replacement in elderly patients based on Japan Adult Cardiovascular Surgery Database. *Circ J* 2012;76:356–64.
- Shahian DM, He X, O'Brien SM, et al. Development of a clinical registry-based 30-day readmission measure for coronary artery bypass grafting surgery. *Circulation* 2014;130:399–409.
- Marcassa C, Giordano A, Giannuzzi P. Five-year hospitalisations and survival in patients admitted to inpatient cardiac rehabilitation after cardiac surgery. *Eur J Prev Cardiol* 2016;23:1609–17.
- Butt JH, Olsen PS, Torp-Pedersen C, Gislason GH, Køber L, Fosbøl EL. Burden and causes for hospitalizations following coronary artery bypass grafting: a nationwide cohort study†. *Eur J Cardiothorac Surg* 2019;55:893–902.
- Trooboff SW, Magnus PC, Ross CS, et al. A multi-center analysis of readmission after cardiac surgery: experience of the Northern New England Cardiovascular Disease Study Group. *J Card Surg* 2019;34:655–62.
- Kim DH, Kim CA, Placide S, Lipsitz LA, Marcantonio ER. Preoperative frailty assessment and outcomes at 6 months or later in older adults undergoing cardiac surgical procedures: a systematic review. *Ann Intern Med* 2016;165:650–60.
- Gomibuchi T, Seto T, Komatsu M, et al. Impact of frailty on outcomes in acute type A aortic dissection. *Ann Thorac Surg* 2018;106:1349–55.
- Rodrigues MK, Marques A, Umeda IIK, Lobo DML, Oliveira MF. Pre-frailty status increases the risk of rehospitalization in patients after elective cardiac surgery without complication. *J Card Surg* 2020;35:1202–8.
- Price JD, Romeiser JL, Gnerre JM, Shroyer AL, Rosengart TK. Risk analysis for readmission after coronary artery bypass surgery: developing a strategy to reduce readmissions. *J Am Coll Surg* 2013;216:412–9.
- Joskowiak D, Wilbring M, Szlapka M, et al. Readmission to the intensive care unit after cardiac surgery: a single-center experience with 7105 patients. *J Cardiovasc Surg (Torino)* 2012;53:671–6.
- Litmathe J, Kurt M, Feindt P, Gams E, Boeken U. Predictors and outcome of ICU readmission after cardiac surgery. *Thorac Cardiovasc Surg* 2009;57:391–4.
- Li Y, Cai X, Mukamel DB, Cram P. Impact of length of stay after coronary bypass surgery on short-term readmission rate: an instrumental variable analysis. *Med Care* 2013;51:45–51.
- Higuchi S, Kabeya Y, Matsushita K, et al. Barthel index as a predictor of 1-year mortality in very elderly patients who underwent percutaneous coronary intervention for acute coronary syndrome: better activities of daily living, longer life. *Clin Cardiol* 2016;39:83–9.

- [18] Uemura Y, Shibata R, Takemoto K, et al. Prognostic impact of the preservation of activities of daily living on post-discharge outcomes in patients with acute heart failure. *Circ J* 2018;82:2793–9.
- [19] Motoki H, Nishimura M, Kanai M, et al. Impact of inpatient cardiac rehabilitation on Barthel index score and prognosis in patients with acute decompensated heart failure. *Int J Cardiol* 2019;293:125–30.
- [20] von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007;370:1453–7.
- [21] JCS Joint Working Group. Guidelines for rehabilitation in patients with cardiovascular disease (JCS 2012). *Circ J* 2014;78:2022–93.
- [22] Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–83.
- [23] Bouillanne O, Morineau G, Dupont C, et al. Geriatric Nutritional Risk Index: a new index for evaluating at-risk elderly medical patients. *Am J Clin Nutr* 2005;82:777–83.
- [24] Niskanen M, Kari A, Nikki P, et al. Acute physiology and chronic health evaluation (APACHE II) and Glasgow coma scores as predictors of outcome from intensive care after cardiac arrest. *Crit Care Med* 1991;19:1465–73.
- [25] Hodgson C, Needham D, Haines K, et al. Feasibility and inter-rater reliability of the ICU Mobility Scale. *Heart Lung* 2014;43:19–24.
- [26] Mahoney FI, Barthel DW. Functional evaluation: the Barthel index. *Md State Med J* 1965;14:61–5.
- [27] Takeuchi K, Furuta M, Okabe Y, et al. Swallowing disorders and 1-year functional decline in community-dwelling older adults receiving home care. *J Oral Rehabil* 2017;44:982–7.
- [28] Bluhmki E, Chamorro A, Dávalos A, et al. Stroke treatment with alteplase given 3.0–4.5 h after onset of acute ischaemic stroke (ECASS III): additional outcomes and subgroup analysis of a randomised controlled trial. *Lancet Neurol* 2009;8:1095–102.
- [29] Di Monaco M, Castiglioni C, De Toma E, Gardin L, Giordano S, Tappero R. Handgrip strength is an independent predictor of functional outcome in hip-fracture women: a prospective study with 6-month follow-up. *Medicine (Baltimore)* 2015;94:e542.
- [30] World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA* 2013;310:2191–4.
- [31] Ministry of Health, Labor and Welfare of Japan. The ethical guidelines for medical and health research involving human subjects (in Japanese). Available at: <https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/hokabun/kenkyujigyou/i-kenkyu/index.html>. Accessed December 20, 2020.
- [32] Lund K, Sibillit KL, Berg SK, Thygesen LC, Taylor RS, Zwisler AD. Physical activity increases survival after heart valve surgery. *Heart* 2016;102:1388–95.
- [33] Waring T, Gross K, Soucier R, ZuWallack R. Measured physical activity and 30-day rehospitalization in heart failure patients. *J Cardiopulm Rehabil Prev* 2017;37:124–9.
- [34] Ahmed HM, Blaha MJ, Nasir K, Rivera JJ, Blumenthal RS. Effects of physical activity on cardiovascular disease. *Am J Cardiol* 2012;109:288–95.
- [35] Arthur HM, Daniels C, McKelvie R, Hirsh J, Rush B. Effect of a preoperative intervention on preoperative and postoperative outcomes in low-risk patients awaiting elective coronary artery bypass graft surgery. A randomized, controlled trial. *Ann Intern Med* 2000;133:253–62.
- [36] Schweickert WD, Pohlman MC, Pohlman AS, et al. Early physical and occupational therapy in mechanically ventilated, critically ill patients: a randomised controlled trial. *Lancet* 2009;373:1874–82.
- [37] Pack QR, Goel K, Lahr BD, et al. Participation in cardiac rehabilitation and survival after coronary artery bypass graft surgery: a community-based study. *Circulation* 2013;128:590–7.
- [38] Goto Y, Itoh H, Adachi H, Ueshima K, Nohara R. Use of exercise cardiac rehabilitation after acute myocardial infarction. *Circ J* 2003;67:411–5.
- [39] Morisawa T, Ueno K, Fukuda Y, et al. Significance of sequential cardiac rehabilitation program through inter-hospital cooperation between acute care and rehabilitation hospitals in elderly patients after cardiac surgery in Japan. *Heart Vessels* 2017;32:1220–6.