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Prognostic Factors among Patients Referred for Inpatient Rehabilitation after Cardiac Surgery

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Abstract

Objective: Comprehensive rehabilitation and continuous management after cardiac surgery are crucial for optimal recovery. Identifying prognostic factors plays a vital role in establishing tailored strategies to enhance recovery outcomes. Therefore, this study aims to identify the factors associated with home discharge among patients who underwent inpatient rehabilitation after cardiac surgery.

Methods: This retrospective study analyzed data from patients transferred to the inpatient rehabilitation department between March 2018 and March 2023 after cardiac surgery. Clinical characteristics, including past medical history, operative factors, and laboratory tests, as well as functional assessments such as the Manual Muscle Test (MMT), Functional Ambulation Category (FAC), and Modified Barthel Index (MBI), were collected. Logistic regression analysis was performed to identify predictors of home discharge, and Cox regression analysis was performed to identify factors associated with mortality.

Results: A total of 94 patients were included. Patients discharged to home (n = 44) showed higher initial and follow-up MBI, FAC, and the sum of MMT, and shorter hospital stays. No significant differences were observed in surgery type, operative factors, or laboratory tests. Multivariate logistic regression analysis identified that initial MBI and length of hospital stay as significant predictors of home discharge. Follow-up MBI was identified as a significant factor predicting post-discharge mortality. Patients with postoperative stroke showed lower initial MBI and FAC and required longer rehabilitation sessions. Significant predictors for home discharge in this subgroup included initial MBI and a higher preoperative ejection fraction.

Conclusion: Patients undergoing cardiac surgery often experience significant functional impairment. Initial MBI at the time of transfer was identified as a key predictor of home discharge, while follow-up MBI was identified as a significant predictor of post-discharge mortality.

Key Words

Stroke, Cardiac surgical procedures, Rehabilitation, Patient discharge

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Introduction

Despite an improvement in surgical techniques, patients undergoing cardiac surgery experience significant loss of health status and quality of life [1]. A study on elective coronary artery bypass graft (CABG) patients showed malnutrition and weight loss during the recovery phase, leading to loss of muscle mass and strength [2,3]. Additionally, complications such as dysphagia contribute to post-surgical disability.

Stroke after cardiac surgery is another major post-operative complication, with an overall incidence of 4.6% [4]. However, new brain infarcts are observed far more frequently than clinical apparent stroke. For instance, a study found that up to 30% of patients exhibited new infarcts on diffusion-weighted imaging after CABG [5]. These infarcts can result from embolisms originating in the heart or arteries, thrombosis due to a hypercoagulable state, and systemic hypoperfusion [6]. Analysis have identified that a history of chronic heart failure (CHF), transient ischemic attack (TIA), and bypass pump time exceeding 120 minutes as significant predictors of stroke after cardiac surgery [7]. Stroke after cardiac surgery is strongly associated with operative morbidity and mortality. A study on patients undergoing coronary and valve surgery demonstrated an in-hospital morality rate of 12.3% for patients with stroke, compared to 6.7% for those without postoperative stroke. These patients also experience longer intensive care unit and hospital stays, along with higher permanent neurologic deficits [8].

Rehabilitation plays a critical role in patients who have undergone major cardiac surgery, regardless of whether they experienced a stroke. Rehabilitation programs, which include risk identification and modification, patient education, and structured exercise aim to improve postoperative health outcomes. Numerous studies have shown that rehabilitation can enhance health outcomes, reduce mortality, and improve quality of life [9,10]. As a result, many patients are transferred to rehabilitation medicine departments to actively participate in rehabilitation, with the ultimate goal of returning to their homes and communities. Several studies have explored predictive factors influencing recovery and home discharge in patients undergoing rehabilitation. Factors such as premorbid disabilities, cognitive dysfunction prior to surgery, and functional abilities at the time of admission have been proposed as potential predictors [11,12]. As an increasing number of patients are receiving inpatient rehabilitation programs, this study aims to investigate the factors related to recovery after cardiac surgery and identify predictors of home discharge among patients referred to rehabilitation departments.

Materials and Methods

Study population

This retrospective study focused on patients who underwent cardiac surgery and subsequently required rehabilitation, spanning from March 2018 to March 2023. Out of the 1588 patients referred to the rehabilitation department for postoperative rehabilitation, 151 (9.5%) were transferred for further extensive rehabilitation. However, 43 of these cases lacked sufficient clinical information, and 13 had experienced acute infarction prior to surgery, while one had a pre-existing spinal cord injury, leaving 94 patients enrolled in our study. Reasons for transfer included deconditioning, dysphagia, and focal weakness. Patients were provided routine care alongside rehabilitation programs tailored to their specific impairments. Those diagnosed with stroke underwent neurodevelopmental treatment, while others participated in cardiac rehabilitation. In addition, patients with postoperative pulmonary compromise received pulmonary rehabilitation. After discharge, they were followed up at the outpatient clinic, and mortality data were collected by the timing of the termination of the patient's national medical insurance coverage. The study protocol was ethically approved by the Institutional Review Board of the hospital (No. 2023-1169), with consent exemption granted due to the retrospective nature of the chart review.

Measurements

The study collected a comprehensive set of data from the enrolled patients, including demographic information, past medical history, radiological findings (including brain magnetic resonance imaging (MRI)), preoperative left ventricular ejection fraction (measured with echocardiography), and baseline laboratory test results. Analysis of the vascular territory and lesion pattern of stroke was conducted based on brain MRI findings. Additionally, information regarding the type of surgery, mean duration of surgery, and the use of cardiopulmonary bypass were meticulously collected.

Functional assessments were conducted using the Manual Muscle Test (MMT) for bilateral shoulder, elbow, wrist, hip, knee, and ankle; the Functional Ambulatory Category (FAC); and the Modified Barthel Index (MBI). These assessments were conducted twice: once after transfer to the rehabilitation department (initial assessment) and again before discharge (follow-up assessment). The FAC scale evaluates patients' ambulation ability on a 6-point scale ranging from 0 to 5, based on the level of human assistance required for walking. A score of FAC 0 indicates inability to walk, while FAC 5 indicates independent ambulation on any surface. The MBI is a tool used to assess functional ability in stroke patients, employing a 5-point system across 14 items. It has demonstrated validity and reliability in measuring patients' independence [13]. The MMT is a numerical grading scale ranging from 0 to 5, commonly used to assess muscle strength. The sum of MMT, calculated by summing the measurements of bilateral shoulder flexion, elbow flexion, wrist flexion, hip flexion, knee flexion and ankle dorsiflexion, ranges from 0 to 60. The validity of the sum of MMT has been established, and it has proven to be a useful tool for predicting mortality and clinical outcomes in critically-ill patients [14,15].

Statistical analysis

All statistical analyses were conducted using IBM SPSS version 21.0 (IBM Corp, Armonk, NY, USA). Continuous variables were compared between patient groups using independent T-tests, while categorical variables were analyzed using Pearson's Chi-squared test. Logistic regression analysis was employed to identify prognostic factors for home discharge. Variables with a p-value of 0.1 or below from univariate analysis were entered and significant variables were selected with the forward method in the multivariable logistic analysis. Multivariate Cox regression analysis was performed for mortality and Kaplan-Meier curves were plotted based on the follow-up MBI (≥ 50 and < 50). Significant variables were determined using the backward selection method. A p-value of < 0.05 was considered statistically significant.

Results

Clinical characteristics according to discharge destination

In the study, a total of 94 patients were included. Among them, 44 were discharged to their homes, 13 were transferred to other departments in the hospital, and 37 were transferred to other hospitals. A comparative analysis between patients discharged home and those discharged elsewhere revealed notable differences. Patients who were discharged home exhibited higher initial and follow-up MBI, FAC, and the sum of MMT. Additionally, patients discharged home had shorter hospital stays compared to those discharged elsewhere (Table 1).

About 58% of patients (55 patients) had post-operative stroke. Comparison between the stroke and non-stroke groups revealed several differences: patients who had strokes had a higher incidence of seizures, lower initial MBI and FAC, and required longer rehabilitation sessions (Supplementary Table 1). Additionally, laboratory analysis indicated that hemoglobin levels were higher in patients

Table 1. Clinical Characteristics According to Discharge Destination

	Home Discharge N = 44	Others N = 50	p-value
Age, year	69.3 ± 10.5	67.9 ± 13.1	0.563
Male, n (%)	22 (50.0%)	34 (68.0%)	0.076
Body mass index	23.2 ± 3.6	22.1 ± 3.5	0.120
Past medical history, n (%)			
Hypertension	19 (43.2%)	23 (46.0%)	0.784
Diabetes	12 (27.3%)	16 (32.0%)	0.617
Dyslipidemia	7 (15.9%)	7 (14.0%)	0.795
Atrial fibrillation	23 (52.3%)	22 (44.0%)	0.423
Previous stroke	3 (6.8%)	6 (12.0%)	0.394
Chronic renal failure	6 (13.6%)	6 (12.0%)	0.812
Smoking, n (%)	15 (34.1%)	19 (38.8%)	0.640
Alcohol, n (%)	14 (31.8%)	20 (40.8%)	0.368
Preoperative ejection fraction (%)	58.6 ± 10.9	52.4 ± 16.0	0.035*
Surgery type, n (%)			0.199
CABG	8 (18.2%)	9 (18.0%)	
Heart valve surgery	28 (63.6%)	32 (64.0%)	
Combined surgery	8 (18.2%)	5 (10.0%)	
Heart transplantation	0	4 (8.0%)	
Operation factors			
Operation time, min	350.3 ± 205.3	376.0 ± 192.9	0.535
Cardiopulmonary bypass use, n (%)	32 (72.7%)	42 (84.0%)	0.192
Laboratory findings			
Hemoglobin, g/dL	11.5 ± 2.1	11.5 ± 2.4	0.988
Creatinine, mg/dL	1.46 ± 1.53	1.55 ± 1.07	0.731
White blood cell, 103/uL	7.65 ± 3.82	8.06 ± 4.90	0.655
C-reactive protein, mg/dL	1.64 ± 3.62	2.61 ±5.60	0.328
Seizure history, n (%)	7 (15.9%)	15 (30.0%)	0.107
Initial functional evaluation			
MBI (0-100)	44.0 ± 24.7	18.8 ± 22.5	< 0.001*
FAC (0-5)	1.98 ± 1.17	1.06 ± 1.27	0.001*
MMT sum (0-60)	45.6 ± 7.6	40.8 ± 9.0	0.007*
Follow-up functional evaluation			
MBI (0-100)	63.1 ± 22.6	33.9 ± 26.1	< 0.001*
FAC (0-5)	2.86 ± 1.25	1.74 ± 1.31	< 0.001*
MMT sum (0-60)	48.2 ± 7.1	41.7 ± 10.8	0.001*
Stroke, n (%)	23 (52.3%)	32 (64.0%)	0.250
Length of hospital stay, days	60.8 ± 32.5	102.6 ± 71.5	< 0.001*
Duration of rehabilitation, days	19.6 ± 5.9	22.5 ± 6.9	0.030*

CABG: carotid artery bypass graft, FAC: Functional Ambulatory Category, MBI: Modified Barthel Index, MMT: manual muscle test

Supplementary Table 1. Clinical Characteristics According to Stroke

	With stroke N = 55	Without stroke N = 39	p-value
Age, year	66.9 ± 13.3	70.8 ± 9.4	0.122
Male, n (%)	33 (60.0 %)	23 (59.0%)	0.920
Body mass index	22.8 ± 3.8	22.4 ± 3.2	0.592
Past medical history, n (%)			
Hypertension	22 (40.0%)	20 (51.3%)	0.278
Diabetes	15 (27.3%)	13 (33.3%)	0.527
Dyslipidemia	6 (10.9%)	8 (20.5%)	0.198
Atrial fibrillation	25 (45.5%)	20 (51.3%)	0.577
Previous stroke	5 (9.1%)	4 (10.3%)	0.850
Chronic renal failure	4 (7.3%)	8 (20.5%)	0.058
Smoking, n (%)	19 (35.2%)	15 (38.5%)	0.746
Alcohol, n (%)	20 (37.0%)	14 (35.9%)	0.910
Preoperative ejection fraction (%)	57.2 ± 12.6	52.8 ± 15.6	0.147
Surgery type, n (%)			0.739
CABG	11 (20.0%)	6 (15.4%)	
Heart valve surgery	36 (65.5%)	24 (61.5%)	
Combined surgery	6 (10.9%)	7 (17.9%)	
Heart transplantation	2 (3.6%)	2 (5.1%)	
Operation factors			
Operation time, min	357.2 ± 200.7	372.4 ± 197.2	0.715
Cardiopulmonary bypass use, n (%)	44 (81.5%)	30 (76.9%)	0.591
Laboratory findings			
Hemoglobin, g/dL	12.1 ± 2.2	10.7 ± 2.1	0.004*
Creatinine, mg/dL	1.27 ± 0.95	1.84 ± 1.68	0.054
White blood cell, 103/uL	7.45 ± 3.29	8.46 ± 5.62	0.280
C-reactive protein, mg/dL	1.45 ± 3.30	3.15 ± 6.22	0.125
Seizure, n (%)	17 (30.9%)	5 (12.8%)	0.041*
Initial functional evaluation			
MBI (0-100)	23.9 ± 26.4	40.1 ± 24.3	0.004*
FAC (0-5)	1.22 ± 1.30	1.85 ± 1.23	0.021*
MMT sum (0-60)	43.1 ± 9.6	43.1 ± 7.23	0.979
Follow up functional evaluation			
MBI (0-100)	43.9 ± 30.1	53.0 ± 25.3	0.123
FAC (0-5)	2.15 ± 1.52	2.44 ± 1.19	0.322
MMT sum (0-60)	44.6 ± 11.3	45.0 ± 7.3	0.857
Home Discharge, n (%)	23 (41.8%)	21 (53.8%)	0.250
Length of hospital stay, days	80.0 ± 68.4	87.4 ± 46.7	0.562
Duration of rehabilitation, days	22.4 ± 6.7	19.4 ± 6.1	0.028*

CABG: carotid artery bypass graft, FAC: Functional Ambulatory Category, MBI: Modified Barthel Index, MMT: manual muscle test

Supplementary Table 2. Clinical Characteristics According to Discharge Destination in Stroke Patients

	Home discharge N = 23	Others N = 32	p-value
Age, year	67.5 ± 10.2	66.5 ± 15.2	0.797
Male, n (%)	11 (47.8%)	22 (68.8%)	0.118
Body mass index	23.9 ± 4.0	21.9 ± 3.5	0.056
Past medical history, n (%)			
Hypertension	7 (30.4%)	15 (46.9%)	0.220
Diabetes	6 (26.1%)	9 (28.1%)	0.867
Dyslipidemia	2 (8.7%)	4 (12.5%)	0.655
Atrial fibrillation	13 (56.5%)	12 (37.5%)	0.162
Previous stroke	0	5 (15.6%)	0.047*
Chronic renal failure	2 (8.7%)	2 (6.3%)	0.730
Smoking, n (%)	7 (30.4%)	12 (38.7%)	0.529
Alcohol, n (%)	7 (30.4%)	13 (41.9%)	0.387
Preoperative ejection fraction (%)	63.4 ± 5.5	52.7 ± 14.4	0.001*
Surgery type, n (%)			0.536
CABG	4 (17.4%)	7 (21.9%)	
Heart valve surgery	17 (73.9%)	19 (59.4%)	
Combined surgery	2 (8.7%)	4 (12.5%)	
Heart transplantation	0	2 (6.3%)	
Operation factors			
Operation time, min	332.7 ± 210.6	382.3 ± 193.7	0.374
Cardiopulmonary bypass use, n (%)	17 (73.9%)	27 (87.1%)	0.217
Laboratory findings			
Hemoglobin, g/dL	12.1 ± 2.2	12.1 ± 2.3	0.961
Creatinine, mg/dL	1.27 ± 1.29	1.27 ± 0.61	0.995
White blood cell, 103/uL	7.51 ± 3.17	7.42 ± 3.42	0.919
C-reactive protein, mg/dL	1.00 ± 2.42	1.77 ±3.82	0.403
Seizure, n (%)	6 (26.1%)	11 (34.4%)	0.512
Initial functional evaluation			
MBI (0-100)	42.3 ± 26.6	9.9 ± 15.5	< 0.001*
FAC (0-5)	1.91 ± 1.34	0.75 ± 1.05	0.001*
MMT sum (0-60)	46.7 ± 8.2	40.4 ± 9.9	0.016*
Follow up functional evaluation			
MBI (0-100)	63.6 ± 25.3	28.8 ± 24.5	< 0.001*
FAC (0-5)	3.00 ± 1.41	1.53 ± 1.30	< 0.001*
MMT sum (0-60)	48.9 ± 7.8	41.4 ± 12.5	0.019*
Length of hospital stay, days	57.2 ± 36.8	96.4 ± 80.8	0.035*
Duration of rehabilitation, days	19.3 ± 6.4	24.7 ± 6.0	0.002*
Lesion laterality			0.724

Supplementary Table 2. Continued.

	Home discharge N = 23	Others N = 32	p-value
Right	7 (30.4%)	7 (21.9%)	
Left	6 (26.1%)	8 (25.0%)	
Bilateral	10 (43.5%)	17 (53.1%)	
Vascular territory			0.265
Anterior circulation	10 (43.5%)	9 (28.1%)	
Posterior circulation	0	4 (12.5%)	
Multiple territory	11 (47.8%)	15 (46.9%)	
Others (unspecified, haemorrhage)	2 (8.7%)	4 (12.5%)	
Lesion patterns			0.867
Cortical	4 (17.4%)	7 (21.9%)	
Subcortical	2 (8.7%)	2 (6.3%)	
Borderzone	2 (8.7%)	5 (15.6%)	
Large territorial	6 (26.1%)	9 (28.1%)	
Others (multiple, haemorrhage)	9 (39.1%)	9 (28.1%)	
Carotid stenosis, n (%)	15 (65.2%)	18 (56.3%)	0.503

CABG: carotid artery bypass graft, FAC: Functional Ambulatory Category, MBI: Modified Barthel Index, MMT: manual muscle test

who had strokes.

In respect of 55 stroke patients, 23 were able to discharge to their homes. A comparison between stroke patients who were discharged home and those who were not revealed significant differences. Stroke patients who discharged to home had less history of previous stroke, higher preoperative ejection fractions, as well as higher scores MBI, FAC, and the sum of MMT (Supplementary Table 2). Additionally, their length of stay in the hospital was shorter, and they received fewer rehabilitation sessions before discharge. While analyzing the vascular territory or lesion patterns, we found no significant differences. However, certain patterns such as bilateral stroke, posterior circulation stroke, and borderzone stroke were less associated with home discharge.

Factors related to home discharge

The logistic regression analysis revealed that both the initial MBI and the length of hospital stay were significant factors in predicting home discharge for all patients. When considering only stroke patients, the analysis showed that the initial MBI remained an independent factor in predicting home discharge, while preoperative ejection fraction showed marginal significance (Table 2).

Factors related to mortality

The median follow-up period was about one year. In the Cox regression analysis, the follow-up MBI was the only significant factor for mortality (OR 0.79, 95% CI of 0.65 – 0.96, p-value = 0.018) (Table 3). The K-M curve for survival according to the follow-up MBI (≥ 50 and < 50) was shown in Fig. 1.

Table 2. Multivariate Logistic Regression Analysis for Home Discharge

	B (SE)	Odds ratio	95% CI	p-value
Patients (N = 94)				
Initial MBI	0.04 (0.01)	1.04	1.01 - 1.06	0.001*
Length of hospital stay, days	-0.02 (0.01)	0.98	0.97 - 0.99	0.007*
Patients with stroke (N = 55)				
Initial MBI	0.06 (0.02)	1.06	1.02 - 1.11	0.004*
Preoperative ejection fraction	0.08 (0.05)	1.08	0.99 - 1.19	0.093

MBI: Modified Barthel Index

Table 3. Multivariate Cox Regression Analysis for Mortality

	B (SE)	Odds ratio	95% CI	p-value
Follow-up MBI	-0.24 (0.10)	0.79	0.65 - 0.96	0.018*

MBI: Modified Barthel Index

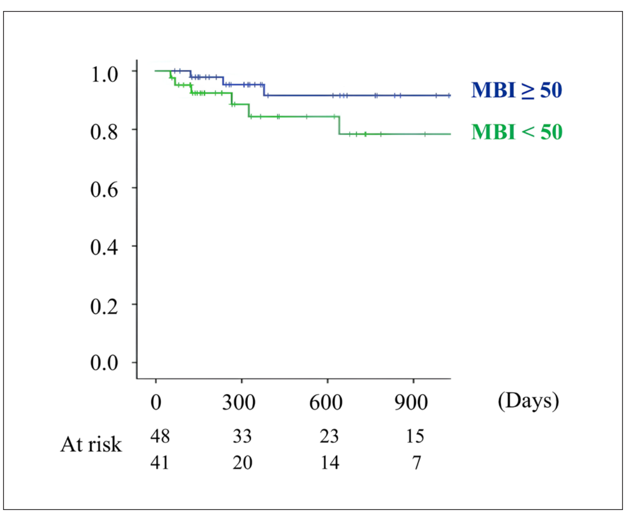

Fig. 1. K-M curves for survival according to the follow-up MBI (≥ 50 and < 50).
MBI: Modified Barthel Index

Discussion

This study showed that initial functional status and length of hospital stay emerged as significant prognostic factors in determining discharge destination for patients who were referred for rehabilitation after cardiac surgery. These results highlight the importance of early functional assessment and tailored interventions to optimize patient outcomes following cardiac surgery. Evaluation in terms of mortality showed follow-up functional status as a significant prognostic factor, indicating importance of continuous evaluation.

Previous study reported that more than 60% of patients had impaired activity of daily living performance post-cardiac surgery [16]. In addition, muscle weakness and deconditioning have been reported, potentially linked to elevated levels of inflammatory cytokines such as interleukin-6 and tumor necrosis factor-α [17,18]. Furthermore, dysphagia is a prevalent issue following cardiac surgery, particularly among patients with prolonged endotracheal intubation [19]. Therefore, a comprehensive rehabilitation approach post-cardiac surgery has been advocated, demonstrating benefits in improving physiologic outcome and enhancing quality of life for patients [20,21].

The initial step in formulating an optimal rehabilitation strategy is setting appropriate rehabilitation goals. Prior research has indicated that patients lacking functional-focused goals tend to experience prolonged hospital stays [22]. Effective goal setting necessitates a comprehensive understanding of the patient's medical and functional status, as well as insight into their natural course and prognosis. In this context, previous studies have sought predictive factors associated with the functional recovery of stroke patients. Age, baseline activities of daily living, and mobility have been identified as significant predictors of functional recovery [23]. Similarly, home discharge, which plays a pivotal role in facilitating early social reintegration and decreasing total medical costs, has been associated with factors such as age, independence in activities of daily living, and social support. [11,24,25]. This study underscores the importance of the initial functional measure, particularly MBI, as the most influential indicator for home discharge. On the other hand, follow-up MBI was an important factor in predicting mortality. The results imply the importance of consistent evaluation including MBI in establishing rehabilitation goal and plan.

It is well known that stroke is a major complication of cardiac surgery. Stroke resulting from different etiologies often exhibits distinct characteristics, including varied responses to treatment [26] and functional outcomes [27]. In line with this, stroke following cardiac surgery shows distinct characteristics, showing more frequent embolic and hypoperfusion etiologies [6]. Despite these variations in etiology and stroke characteristics, our study supports previous findings indicating the initial functional status significantly influences prognosis, particularly regarding the home discharge [23]. This study also suggests that the pre-operative ejection fracture may be related to stroke patients' home discharge. Patients who discharged to their home showed higher ejection fraction than those who could not, and the tendency was consistent within stroke patients. Previous research showed that left ventricle ejection fraction was a powerful predictor of stroke in patients after myocardial infarction [28]. Patients with worse ventricular function showed more venous and arterial embolic events in various studies as well [29,30]. Ejection fraction was also associated with clinical outcome of stroke patients [31,32]. The low ejection fraction groups had lower functional independence measure at discharge, lower functional gains and efficiency [33]. The present study also implies that stroke patients with higher pre-operative ejection fraction may show better outcome and lead to higher chance of discharge to home.

This study is subject to several limitations. Firstly, its retrospective nature and relatively small sample size may restrict the generalizability of the findings. Future research with larger patient cohorts and a prospective study design would enhance the robustness and applicability of the results. Moreover, conducting subgroup analyses based on stroke territory or vascular patterns could yield valuable insights into the specific mechanisms underlying stroke occurrence following cardiac surgery. Additionally, our study only included patients who opted for rehabilitation treatment and were subsequently transferred to rehabilitation services post-surgery. This approach may have excluded individuals with very mild neurological deficits or severe disease, potentially skewing the sample towards those more likely to benefit from rehabilitation. In addition, evaluation tools such as the 6-minute walking test or grip strength, which provide information about a patient's fitness and cardiopulmonary performances, could have contributed further insights. Lastly, confounding factors such as socioeconomic status, physical activity, and mental health were not considered in this study.

Conclusion

The findings of this study underscore significant predictors of home discharge among patients undergoing cardiac surgery and subsequent inpatient rehabilitation. Specifically, higher initial MBI scores and shorter hospital stays were closely associated with discharge to home, while follow-up MBI scores were associated with mortality. Among patients who had a stroke, those with higher preoperative ejection fractions implied a greater likelihood of being discharged to home. Overall, these results suggest that tailored interventions and support strategies would be needed to enhance patient outcomes and facilitate successful transitions to home following cardiac surgery and rehabilitation.

Conflicts of interest

None to declare

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