Effects of acute-phase multidisciplinary rehabilitation on unplanned readmissions after cardiac surgery

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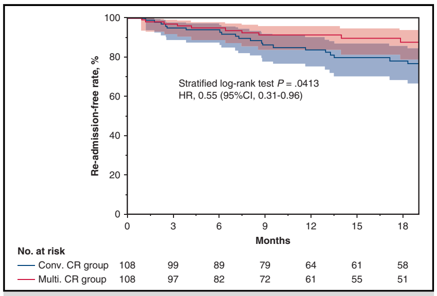
ABSTRACT

Objectives: The provision of inpatient programs that reduce the incidence of readmission after cardiac surgery remains challenging. Investigators have focused on multidisciplinary cardiac rehabilitation (CR) because it reduces the postoperative readmission rate; however, most previous studies used outpatient models (phase II CR). We retrospectively investigated the effect of comprehensive multidisciplinary interventions in the acute inpatient phase (phase I CR) on unplanned hospital readmission.

Methods: In a retrospective cohort study, we compared consecutive patients after cardiac surgery. We divided them into the multidisciplinary CR (multi-CR) group or conventional exercise-based CR (conv-CR) group according to their postoperative intervention during phase I CR. Multi-CR included psychological and educational intervention and individualized counseling in addition to conv-CR. The primary outcome was unplanned readmission rates between the groups. A propensity score–matching analysis was performed to minimize selection biases and the differences in clinical characteristics.

Results: In our cohort (n = 341), 56 (18.3%) patients had unplanned readmission during the follow-up period (median, 419 days). Compared with the conv-CR group, the multi-CR group had a significantly lower unplanned readmission rate (multivariable regression analysis; hazard ratio, 0.520; 95% confidence interval, 0.28-0.95; *P* = .024). A Kaplan–Meier analysis of our propensity score–matched cohort showed that, compared with the conv-CR group, the multi-CR group had a significantly lower incidence of readmission (stratified log-rank test, *P* = .041).

Conclusions: In phase I, compared to conv-CR alone, multi-CR reduced the incidence of unplanned readmission. Early multidisciplinary CR can reduce hospitalizations and improve long-term prognosis after cardiac surgery. (J Thorac Cardiovasc Surg 2021;161:1853-60)



Multidisciplinary cardiac rehabilitation improves unplanned readmission-free survival.

CENTRAL MESSAGE

Comprehensive multidisciplinary cardiac rehabilitation during the acute inpatient phase after cardiac surgery is important for patient management and preventing unplanned readmission.

PERSPECTIVE

Cardiac rehabilitation after cardiac surgery has been underused worldwide. Multidisciplinary cardiac rehabilitation focused on patient education and disease self-management during the early postoperative stage can reduce subsequent hospitalizations. These data suggest the importance of acute phase cardiac rehabilitation and the continuity of rehabilitative care after cardiac surgery.

See Commentaries on pages 1861 and 1862.

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Abbreviations and Acronyms

AF = atrial fibrillation
BMI = body mass index
CI = confidence interval
Conv-CR = conventional exercise-based cardiac rehabilitation
CR = cardiac rehabilitation
HR = hazard ratio
Multi-CR = multidisciplinary cardiac rehabilitation
QOL = quality of life

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In recent decades, the increased use of fast-track recovery protocols after cardiac surgery has significantly reduced the postoperative hospital length-of-stay and cost of care without increasing postoperative mortality or morbidity.[1,2] Ironically, because many patients are discharged without an adequate assessment of residual cardiovascular risks, medication titration, physical rehabilitation, or educational intervention, these protocols also increased the rate of unplanned postoperative hospital readmission.[3,4] Notably, previous studies showed that approximately 20% of patients who underwent cardiac surgery were readmitted within 30 days after discharge, resulting in greater medical costs.[4,5]

Current clinical guidelines address this issue by emphasizing the importance of exercise-based cardiac rehabilitation (CR), which effectively improves symptoms and exercise capacity; consequently, it is expected to decrease the rate of readmission.[6] Currently, in addition to conventional exercise-based CR, comprehensive multidisciplinary interventions are recommended to address the impaired quality of life, depressive symptoms, and other disease-related problems that can occur after cardiac surgery. Multidisciplinary cardiac rehabilitation (multi-CR) includes dedicated care with psychoeducational components, nutritional support, and exercise training. Several randomized controlled trials have identified lifestyle interventions and educational programs that improve health outcomes and reduce the risk of a new cardiac event after cardiac surgery by modifying unhealthy behaviors.[7,8] However, almost all of these CR interventions were carried out during phase II, which begins after discharge. Given that rehospitalization is reached approximately 20% within 30 days after discharge, we believe that it is very important to intervene during an earlier phase. However, to our knowledge, very few investigators have evaluated the impact of comprehensive multidisciplinary CR administered in the hospital immediately after cardiac surgery (phase I) on readmission rates.

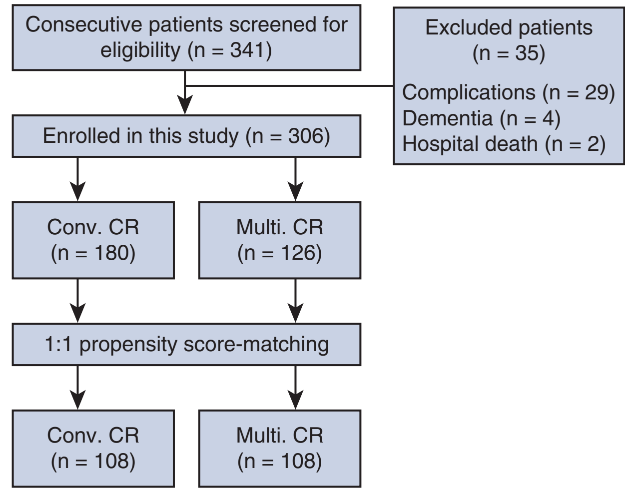


FIGURE 1. Study flow chart. *Conv. CR*, Conventional exercise-based cardiac rehabilitation; *Multi. CR*, multidisciplinary cardiac rehabilitation.

Therefore, we investigated the effects of comprehensive multidisciplinary phase I CR interventions, including educational programs designed to help patients self-manage their disease. We aimed to evaluate whether a comprehensive multidisciplinary phase I CR can improve cardiovascular event prevention and reduce unplanned hospital readmissions compared with conventional exercised-based CR alone.

MATERIALS AND METHODS

Study Population

The present study was a retrospective analysis conducted at a single center. The study flow chart is shown in Figure 1. We retrospectively compared consecutive patients who underwent elective cardiac surgery (eg, coronary artery bypass surgery, valve replacement or repair, or coronary artery bypass surgery with concomitant valve replacement or repair) between December 2015 and April 2017 according to the postoperative CR intervention they had received during phase I CR. We excluded patients with a psychiatric disorder or severe dementia and those who could not complete the CR program due to postoperative complications such as respiratory failure, stroke, or hospital death. The study complied with the principles of the Declaration of Helsinki regarding investigations in human subjects and was approved by the Kobe University Institutional Review Board (approval no.180182). Written informed consent was obtained from each patient before their cardiac surgery.

Patient Clinical Characteristics

We evaluated baseline characteristics, including age; sex; body mass index; left ventricular ejection fraction; estimated glomerular filtration rate; brain natriuretic peptide, hemoglobin, serum albumin, and C-reactive protein levels; comorbidities; medications; and the European System for Cardiac Operative Risk Evaluation II.[9] Laboratory data were evaluated within 1 week before cardiac surgery. We recorded operative variables, including the type and duration (in minutes) of cardiac surgery and postoperative variables including type of phase I CR, hospital mortality, length of intensive care unit stay, length of hospital stay, and postoperative surgery-related complications. Health-related quality of life (QOL) was investigated with the Japanese version of the Medical Outcomes Study 36-Item Short-Form General Health Survey Version 2.0.[10] The primary endpoint was unplanned hospital readmission after discharge during the follow-up period.[11] We defined unplanned readmission as any type of emergency readmission (including emergency fast-track or an urgent admission requested by the general practitioner). Planned readmissions were excluded, which were defined as readmissions that were classified as elective. The patients were followed-up as outpatients, and the date and cause of any reported event were determined during regularly scheduled outpatient visits and confirmed by review of hospital medical records.

Intervention for Postoperative Rehabilitation

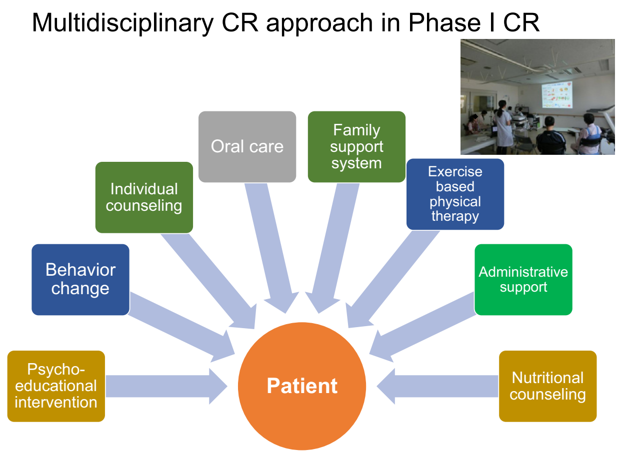
All patients received CR beginning the day after surgery until hospital discharge per the Japanese Circulation Society guidelines for rehabilitation of patients with cardiovascular disease as a standard of care,[6] but none of the patients received phase II CR after discharge. We divided them into the multi-CR group or conventional exercise-based CR (conv-CR) group according to the postoperative intervention they had received during phase I CR. The multidisciplinary rehabilitation team consisted of dedicated medical practitioners focused on improving care for elderly patients. We implemented a twice-weekly multidisciplinary conference to review patients scheduled for cardiac surgery. Our team recruited consenting patients who had a great need for psychoeducational intervention, including those with many comorbidities and unhealthy lifestyle habits. Patients who did not require this treatment based on our team assessment or those who did not consent to multi-CR received conv-CR.

Exercise-Based Rehabilitation Program (Conv-CR)

CR programs were implemented during the inpatient period for approximately 2 weeks and were based on Japanese Circulation Society guidelines.[6] CR mainly focused on exercise training and the prevention of postoperative complications. Physical training included a half hour of personalized aerobic exercise each weekday and daily resistance exercise for approximately 1 hour. Aerobic exercise sessions involved monitored use of a cycle ergometer or treadmill walking at the intensity of 11 to 13 on the Borg scale. The heart rate and oxygen saturation were measured at each session, and patients used pulse watches during cycle training. Muscle and endurance exercises consisted of sit-to-stand and heel lifting exercises with an increasing number of repetitions. The in-hospital physical training was supervised by a physiotherapist. Because patients had undergone a sternotomy, we did not prescribe upper-body strength training to avoid complications such as an unstable sternum and exercises that primarily targeted lower-body muscles. If necessary, patients underwent respiratory physiotherapy consisting of deep breathing exercises.

Multidisciplinary Rehabilitation Program (Multi-CR)

Multi-CR consisted of twice-weekly group education and discussion sessions and individualized counseling in addition to conv-CR. Multi-CR focused on psychoeducational intervention to improve patients' coping strategies, improve disease management, provide information, promote self-monitoring of their heart failure symptoms, and help resume daily life after cardiac surgery (Video 1). Each educational and counseling session lasted approximately 1 hour. This component included classes conducted by a cardiologist, cardiology nurses, and a nutritionist. These sessions aimed to change habits that adversely affect the risk of cardiovascular diseases through the use of coping strategies and disease management, provide information, and help patients resume daily activities after cardiac surgery. CR personnel also helped patients incorporate self-care



VIDEO 1. Dr Ogawa, the first author and principal statistician of this study, explains the background, major findings, and key relevance of the present study. Video available at: https://www.jtcvs.org/article/S0022-5223(19)36114-8/fulltext.

behaviors into their daily routine. The educational program was offered to patients' caregivers as well.

Professional nursing education included teaching patients how to manage their heart failure symptoms, measure their pulse, recognize an arrhythmia or infection, monitor their weight and surgical sites, and optimize their cardioprotective medications. Nurses also provided information about smoking cessation, coping with stress, and daily physical activity.

A nutritionist identified comorbidities, including chronic kidney disease, obesity, hypertension, diabetes, and dyslipidemia; provided appropriate meals in the hospital; and explained the necessity of continuing this diet after discharge. The nutritionist also provided education about water management, salt restriction, and daily alcohol consumption.

Statistical Analysis

We conducted statistical analyses after confirming that the data were normally distributed using the Shapiro–Wilk test. Patients were separated into the conv-CR or multi-CR group, and between-group differences in clinical characteristics were compared using the independent t and χ^2 tests. We adjusted for baseline characteristics using propensity scores to reduce the risk of bias in treatment selection and other potential confounding factors because patients were not randomly assigned to a CR group.[12] To produce propensity scores, a logistic regression analysis was performed with CR group as the dependent variable and the 22 variables listed in Table 1 as independent variables (c statistic = 0.721). We performed a 1:1 nearest available matching on the logit of the propensity score with a caliper value of 0.2 and no replacement. We used the standardized mean difference to measure covariate balance, whereby an absolute standardized mean difference <0.1 represents a meaningful imbalance between groups. In the matched cohort, paired comparisons were performed with the use of the McNemar test for binary variables and a paired Student t test for continuous variables. Association between CR modality and unplanned readmission was evaluated by using a proportional hazards regression model stratified on matched pairs to preserve the benefit of matching. Unplanned readmission was compared using the Fine–Gray model, which adjusted for death as a competing risk.[13] Proportional hazard assumption was checked both graphically and using the Schoenfield residual test. In the entire cohort, the multivariable proportional-hazards regression model with the stepwise backwards (Wald) method from factors with P values <.10 in the univariable analysis of the entire cohort was performed to calculate hazard ratios (HRs) and the impact of CR on unplanned readmission. We estimated

TABLE 1. Baseline clinical characteristics of conventional and multidisciplinary cardiac rehabilitation groups

	All study patients				Propensity-matched population			
Variables	Conv-CR	Multi-CR	Standardized mean differences	*P* value	Conv-CR	Multi-CR	Standardized mean differences	*P* value
Number	180	126			108	108		
Age, y	67.0 ± 14.5	67.6 ± 12.9	0.043	.692	67.4 ± 13.4	67.3 ± 13.2	0.007	.941
Sex, female (%)	75 (41.7)	49 (38.9)	0.057	.626	38 (35.2)	43 (39.8)	0.010	.596
BMI, kg/m^2	22.9 ± 3.7	23.4 ± 4.3	0.124	.270	23.0 ± 3.8	23.1 ± 4.3	0.024	.821
Albumin, g/dL	4.0 ± 0.5	4.0 ± 0.5	0.040	.837	3.9 ± 0.6	4.0 ± 0.5	0.018	.879
BNP, pg/mL	248.5 ± 382.1	231.7 ± 294.2	0.049	.677	217.9 ± 347.6	231.0 ± 298.6	0.043	.778
Hemoglobin, g/dL	12.4 ± 1.9	12.7 ± 1.7	0.166	.142	12.7 ± 1.9	12.7 ± 1.6	0.001	.905
LVEF, %	58.5 ± 13.2	60.3 ± 10.7	0.150	.194	59.5 ± 13.3	59.8 ± 11.0	0.025	.850
Hypertension, n (%)	82 (45.6)	76 (60.3)	0.297	.011	62 (57.4)	61 (56.5)	0.018	.922
Dyslipidemia, n (%)	47 (26.1)	53 (42.1)	0.322	.003	36 (33.3)	42 (38.9)	0.097	.391
Diabetes, n (%)	37 (20.6)	41 (32.5)	0.272	.018	31 (28.7)	30 (27.8)	0.020	.923
Chronic kidney disease, n (%)	93 (51.7)	57 (45.2)	0.130	.268	51 (47.2)	52 (48.2)	0.020	.892
Atrial fibrillation, n (%)	40 (22.2)	39 (31.0)	0.200	.086	32 (29.6)	29 (26.9)	0.060	.766
Smoking, n (%)	23 (12.8)	16 (12.7)	0.003	.984	13 (12.0)	14 (13.0)	0.030	.864
Type of surgery, n (%)								
Valve	130 (72.2)	87 (69.1)	0.068	.880	76 (70.4)	75 (69.4)	0.022	.955
CABG	16 (8.9)	12 (9.5)			9 (8.3)	11 (10.2)		
Concomitant	34 (18.9)	27 (21.4)			23 (21.3)	22 (20.4)		
NYHA class n (%)								
I	32 (17.8)	28 (22.2)	0.020	.279	23 (21.3)	22 (20.4)	0.020	.779
II	91 (50.6)	65 (51.6)			57 (52.8)	56 (51.9)		
III	53 (29.4)	33 (26.2)			28 (25.9)	30 (27.8)		
Duration of surgery, min	347.5 ± 110.6	335.6 ± 91.0	0.118	.322	343.8 ± 102.8	333.2 ± 87.0	0.092	.481
EuroSCORE II	5.9 ± 3.8	6.8 ± 3.7	0.240	.032	6.6 ± 4.0	6.7 ± 3.1	0.028	.807
Medications, n (%)								
β-blocker	112 (62.2)	97 (77.0)	0.326	.006	74 (77.3)	74 (76.3)	0.024	.784
ACE-I	38 (21.1)	37 (29.4)	0.192	.950	22 (22.7)	22 (22.7)	<0.001	1.000
ARB	35 (19.4)	45 (35.7)	0.371	.001	28 (28.9)	26 (26.8)	0.047	.451
Statin	50 (27.8)	46 (36.5)	0.187	.105	30 (30.9)	31 (32.0)	0.024	.770
Diuretics	85 (47.2)	66 (52.4)	0.104	.374	49 (50.5)	47 (48.5)	0.040	.774

Data are expressed as means ± standard deviation or number (percentage). *Conv-CR*, Conventional exercise-based cardiac rehabilitation; *Multi-CR*, multidisciplinary cardiac rehabilitation; *BMI*, body mass index; *BNP*, brain natriuretic peptide; *LVEF*, left ventricular ejection fraction; *CABG*, coronary artery bypass grafting; *NYHA*, New York Heart Association; *ACE-I*, angiotensin converting enzyme inhibitor; *ARB*, angiotensin II receptor blocker.

overall unplanned readmission-free survival between conventional CR group and multidisciplinary CR group by using Kaplan–Meier curves for all patients and a propensity score–matched cohort. In the matched cohort, we compared overall readmission-free survival in both groups by using the stratified log-rank test. The sample size was calculated with referring to the previous paper[14] and our unpublished data (power = 0.8, significance level = 0.05, mean difference = 14.0%; n = 300 patients). A *P* value <.05 was considered statistically significant. Statistical analyses were carried out using JMP 11.0J software (SAS Institute Inc, Cary, NC).

RESULTS

During the study period, 341 patients presented for surgery. Of these, 35 were excluded (Figure 1) and 306 (mean age, 67.5 ± 13.1 years; median follow-up, 419 days [interquartile range, 211-712]) were analyzed. There were 180 and 126 patients in the conv-CR and multi-CR groups, respectively. Propensity score matching identified 216 matched pairs for comparison (c statistic = 0.721; Table 1, Figure E1). No residual imbalance was observed between matched groups (P > .10 for all variables). Furthermore, the covariate balance in the matched cohort was considerably improved; the absolute standardized mean difference was <0.1. After propensity score-matching, the follow-up periods in the multi-CR and conv-CR groups were comparable (458.5 ± 296.9 days vs 448.2 ± 267.0 days).

TABLE 2. Comparison of clinical outcomes of conventional and multidisciplinary cardiac rehabilitation groups

	All study patients				Propensity-matched population			
Variables	Conv-CR	Multi-CR	Standardized mean differences	*P* value	Conv-CR	Multi-CR	Standardized mean differences	*P* value
Length of hospital stay, d	22.0 ± 21.0	20.0 ± 10.2	0.135	.158	21.8 ± 24.3	20.1 ± 10.8	0.090	.240
Follow up, d	453.4 ± 304.7	405.2 ± 269.8	0.167	.959	458.5 ± 296.9	448.2 ± 267.0	0.364	.791
Unplanned readmission, n (%)	39 (21.7)	17 (13.5)	0.217	.065	28 (25.9)	13 (12.0)	0.360	.0148
Death, n (%)	1 (0.6)	1 (0.8)	0.024	.799	0 (0.0)	1 (1.0)	0.045	.222

Conv-CR, Conventional exercise-based cardiac rehabilitation; *Multi-CR*, multidisciplinary cardiac rehabilitation.

Table 2 compares the clinical results and incidence of unplanned readmission before and after matching. Length of hospital stay and QOL at hospital discharge were not significantly different between the 2 groups (Table E1). Overall, 56 patients (18.3%) had unplanned readmission (heart failure, n = 31; infection, n = 11; arrhythmia, n = 8; stroke, n = 3; pneumonia, n = 2; nonfatal myocardial infarction, n = 1). After propensity score matching, the incidence of unplanned readmission was significantly lower in the multi-CR group than in the conv-CR group (*P* = .0148). A global test based on Schoenfield residuals found that all covariates and the full model satisfied the proportional hazard assumption. A univariable proportional hazards analysis for predicting unplanned readmission in the entire cohort showed no significant difference between the CR groups (*P* = .174). However, multivariable regression analyses of unmatched patients showed that compared with conv-CR, multi-CR independently predicted a decreased rate of unplanned readmission (HR, 0.504; 95% confidence interval [CI], 0.282-0.901; *P* = .021; Table 3). Similarly, multi-CR independently predicted a reduced rate of unplanned readmission in our comparison of the propensity score–matched cohorts (HR, 0.520; 95% CI, 0.277-0.949; *P* = .024; Table 4). The results of the Kaplan–Meier analysis are shown Figure 2 and Figure E2. The cumulative incidence of unplanned readmission for the multi-CR group was significantly lower than that for the conv-CR group in propensity score–matched cohorts (stratified log-rank test, *P* = .0413; HR, 0.55; 95% CI, 0.31-0.96; Figure 2).

TABLE 3. Fine–Gray proportional hazard regression for readmission-free survival after multidisciplinary cardiac rehabilitation for all patients (n = 306)

Model	Hazard ratio (95% CI)	*P* value	Proportional hazard assumption *P* value
Unadjusted	0.671 (0.377-1.193)	.174	.155
Adjusted for age and sex	0.650 (0.365-1.157)	.143	.232
Multivariable adjusted*	0.504 (0.282-0.901)	.0207	.180

Reference: conventional cardiac rehabilitation group. *CI*, Confidence interval. *Adjusted for age, hypertension, diabetes, dyslipidemia.

DISCUSSION

To the best of our knowledge, this is the first study to demonstrate the effectiveness of comprehensive multidisciplinary phase I CR after cardiac surgery. We showed that our comprehensive multi-CR program was independently associated with a significant reduction in postoperative unplanned readmission compared with conv-CR alone after adjusting for many confounding variables. Several investigators have reported the beneficial effects of multi-CR. However, these studies were of phase II CR. We are the first to demonstrate that phase I multi-CR can effectively reduce the incidence of long-term adverse outcomes. Furthermore, few studies have compared the effects of exercise-based and comprehensive multi-CR. The aim of phase I CR is to minimize the effects of inactivity and maintain or improve muscle strength and mobility.[6] Exercise-based phase I CR effectively improves exercise capacity and prevents cardiac events after cardiac surgery.[3,14,15] Notably, our study demonstrated that multidisciplinary educational intervention in addition to exercise-based CR were more effective than exercise-based CR alone even during phase I.

In our cohort, the patients in the multi-CR group had many comorbidities and high surgical risk, as shown by their European System for Cardiac Operative Risk Evaluation. Our selection method, which involved intentionally recruiting high-risk patients into the multi-CR group, may explain the differences between our 2 study groups. We did not observe a statistically significant reduction in hospital readmission between the conv-CR and multi-CR groups. Nevertheless, it is interesting to note that, when we used a propensity score–matching method to reduce the confounding effect due to differences in demographics between the 2 groups, multi-CR was independently associated with a significant reduction in unplanned readmission compared with conv-CR. Our results suggested that multi-CR is useful

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TABLE 4. Fine–Gray proportional hazard regression for readmission-free survival after multidisciplinary cardiac rehabilitation for propensity score-matched patients (n = 216)

Model	Hazard ratio (95% CI)	P value	Proportional hazard assumption P value
Unadjusted	0.552 (0.283-0.987)	.040	.695
Adjusted for propensity	0.520 (0.277-0.949)	.0235	.722

Reference: conventional cardiac rehabilitation group. *CI*, Confidence interval.

regardless of the patient's background and comorbidities. Previous studies of phase II CR found that patients with an adverse risk factor profile or a poor understanding of risk factors are not likely to attend CR sessions and have low adherence to CR.[16] Furthermore, the CR participation rate is lower in proportion to the delay in CR enrollment after discharge.[17,18] Phase I CR is conducted in the hospital; thus, the participation rate tends to be greater than that of phase II CR. Therefore, we believe that phase I is an opportune time to begin changing lifestyle habits and improving physical activity in patients at high risk for readmission.

In this study, the incidence of unplanned readmission was 18.3%, which is similar to that of previous studies carried out after cardiac surgery.[4,19] More than one half of these readmissions were for worsening heart failure, often accompanied by volume overload. Previous studies found that most readmissions for heart failure exacerbation are attributable, at least in part, to poor self-care, including noncompliance with medication and diet recommendations and failure to act upon escalating symptoms.[20] Moreover, most heart failure readmissions are caused by factors that patients can be taught to recognize and avoid.[21] We used a wide variety of multidisciplinary strategies focused on patient education and self-management to reduce hospitalizations. Furthermore, it is highly likely that the effects of our multidisciplinary phase I CR educational program persisted long after discharge. A review of interventions promoting self-care in patients with heart failure revealed that specific components, including group-based programs and frequent contact and supervision by researchers or health team members, appear to promote positive outcomes.[22] Thus, phase I is a critical window of opportunity for initiating disease self-management education, especially for high-risk patients.

The second most common cause of readmission was infection, including superficial and deep sternotomy infections. Surgical-site infections require meticulous wound care and antibiotics and are complications that could be prevented through quality improvement initiatives. Arrhythmia was also a common cause of readmission. Postoperative atrial fibrillation (AF) occurred frequently, and the risk of AF persisted after discharge. Reportedly, a nurse-led education program that teaches patients how to self-palpate their pulse may be a useful method for screening asymptomatic AF. However, the effect of self-

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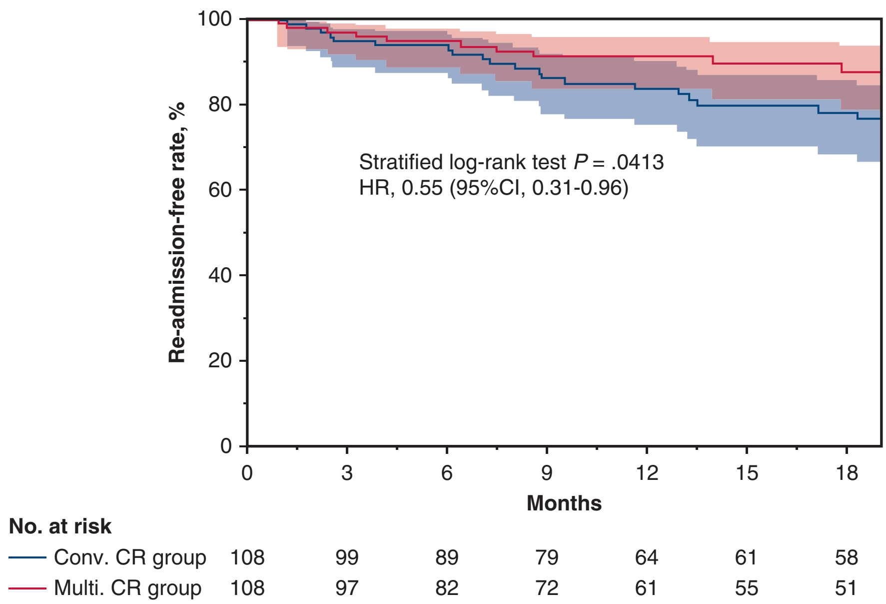

FIGURE 2. The Kaplan–Meier survival curves for cumulative unplanned readmission after cardiac surgery between the conv-CR group (*blue line*) and multi-CR groups (*red line*) in a propensity score–matching cohort. The incidence of unplanned readmission in the multi-CR group was significantly lower than that in the conv-CR group (stratified log-rank test, $P = .0413$). We also revealed confidence limits as the shaded area. *HR*, Hazard ratio; *CI*, confidence interval; *Conv-CR*, conventional exercise-based cardiac rehabilitation; *Multi-CR*, multidisciplinary cardiac rehabilitation.

pulse palpation on long-term cardiac events remains poorly understood.[23] Future studies of postoperative AF management after discharge are warranted. Although we could not analyze what component of multi-CR was effective, we think multidisciplinary CR education program for patients and their caregivers effectively promoted heart failure symptom monitoring and daily infection surveillance. In particular, we believe that it is most important to educate patients about self-monitoring and self-management of heart failure symptom by nutritionist or professional nurses.

Recent guidelines for cardiac rehabilitation include a Class I recommendation for patients to receive specific education about heart failure self-care.[6] Nevertheless, phase II CR is underused worldwide. Phase II CR was only provided to 30% of patients in Europe, 25% in the United States, and 9% in Japan.[24,25] Institutional practices, health care system practices, and health insurance system practices could explain this low rate of participation. The underuse of phase II CR suggests there is a problem with the continuity of care from inpatient to outpatient rehabilitation. As the rate of phase II CR participation is very low (including formulated exercise prescriptions and patient education programs), phase I CR is of substantial importance to patient management. A recent study demonstrated that patient compliance with phase II CR might be increased with home-based CR or telemonitoring.[26] We believe that CR including patient education and disease management and close cooperation with general practitioner from the early postoperative period may be effective for preventing hospital readmission after cardiac surgery. Future studies investigating the transition from phase I to phase II CR are needed to improve the continuity of rehabilitative care after cardiac surgery.

Our study had several limitations. First, the study was a retrospective analysis, and no contemporary control group was available for comparison. Therefore, a type 2 statistical error cannot be excluded because of low statistical power to detect a difference between the 2 groups. However, patients included in our study population could represent a more representative sample of "real-world" patients undergoing cardiac surgery than those included in many of the randomized controlled trials that have previously evaluated CR effectiveness. Second, our recruitment method may have introduced selection bias, although several different statistical methods were used to adjust for baseline characteristics and confirm the results. There was a possibility that systematic error, bias or hidden confounders, and not true biological effects could occur. Third, we did not adjust for all confounding factors such as patient personality, motivation, or attitude toward CR. Our results may not be generalizable to patients who choose not to enroll in CR programs. Next, we did not have data about cost of CR or the outcomes of long-term QOL. Therefore, we cannot mention whether multidisciplinary CR programs are cost-effective. Furthermore, we could not continue phase II CR after discharge or investigate the effects of general practitioner after discharge and the frequency of intervention in detail. Finally, the lack of complete socioeconomic data, including education and income levels, also limited the study.

In conclusion, this study of the effects of phase I CR after cardiac surgery revealed that, compared with conv-CR alone, comprehensive multi-CR reduced the incidence of unplanned readmission after adjusting for confounding factors. Multi-CR focused on patient education and disease self-management in the early postoperative stage can reduce subsequent hospitalizations. Future studies investigating the clinical effects of phase I CR on long-term outcomes and the transitions between CR phases are needed to improve the care of patients undergoing cardiac surgery.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: cardiac surgery, multidisciplinary cardiac rehabilitation, readmission, acute phase, propensity score

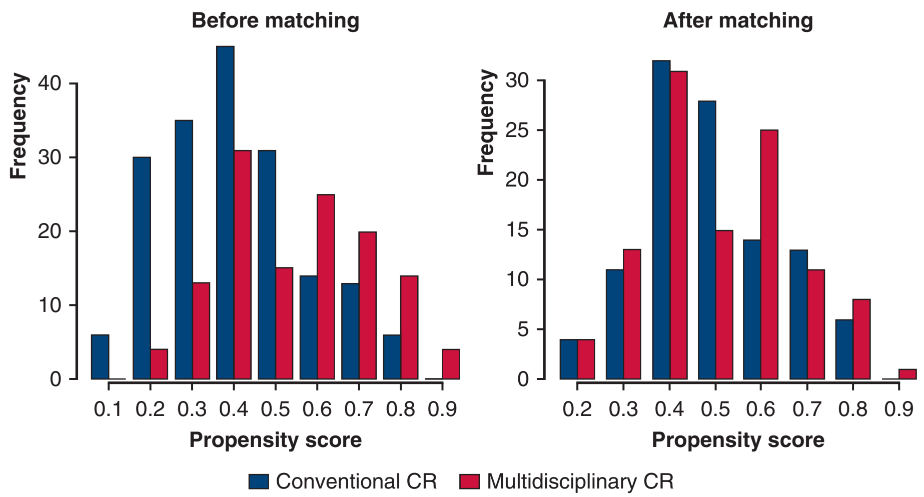

FIGURE E1. Comparison of propensity score distributions before and after matching between the conventional and multidisciplinary cardiac rehabilitation groups. *CR*, Cardiac rehabilitation.

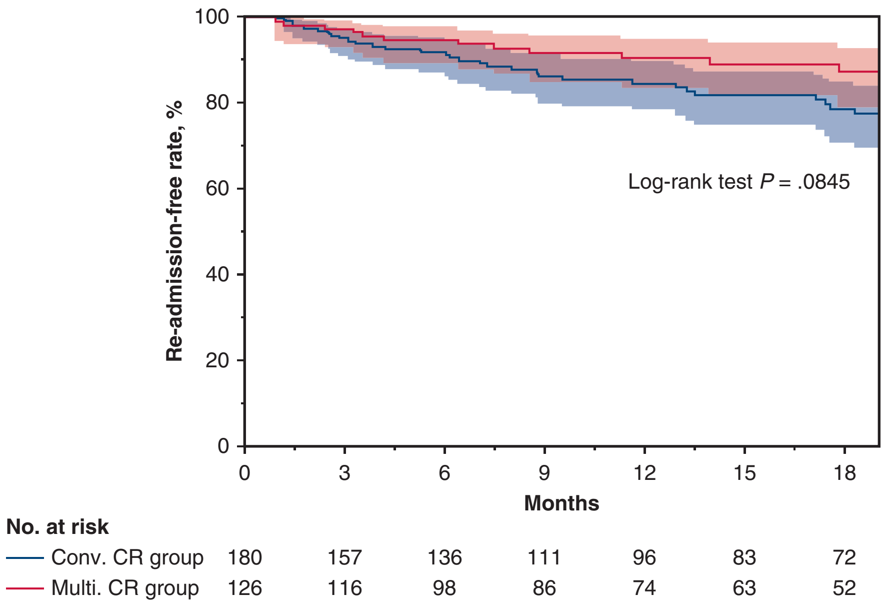

FIGURE E2. The Kaplan–Meier survival curves for cumulative unplanned readmission after cardiac surgery between the conv-CR group (*blue line*) and multi-CR groups (*red line*) in the entire cohort. The incidence of unplanned readmission was not significantly different between the multi-CR group and the conv-CR group (log-rank test, $P = .0845$). We also revealed confidence limits as a *shaded area*. *Conv-CR*, Conventional exercise-based cardiac rehabilitation; *Multi-CR*, multidisciplinary cardiac rehabilitation.

TABLE E1. Comparison of health-related quality of life at hospital discharge after surgery in conventional and multidisciplinary cardiac rehabilitation groups

	All study patients				Propensity-matched population			
Variables	Conv-CR	Multi-CR	Standardized mean differences	*P* value	Conv-CR	Multi-CR	Standardized mean differences	*P* value
PCS	38.7 ± 12.6	39.0 ± 13.2	2.325	.910	38.7 ± 12.8	40.1 ± 13.1	10.810	.646
MCS	51.9 ± 11.3	53.9 ± 9.2	19.410	.412	51.8 ± 11.1	53.6 ± 9.6	17.346	.480

Conv-CR, Conventional exercise-based cardiac rehabilitation; *Multi-CR*, multidisciplinary cardiac rehabilitation; *PCS*, Physical Component Summary; *MCS*, Mental Component Summary.