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In-patient step count predicts re-hospitalization after cardiac surgery

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ABSTRACT

Background: Clinical significance of in-patient step count after cardiac surgery remains unknown. The aim of this study was to determine whether the number of steps walked during the in-patient stay after cardiac surgery predicts the risk of cardiac re-hospitalization in the following year.
Methods: One hundred and thirty-three patients who underwent cardiac surgery were included in this study. The number of steps was assessed using a triaxial accelerometer. One year after surgery, patients completed a postal survey to determine their health condition and occurrence of cardiac re-hospitalization.
Results: The mean number of steps walked during the last three in-patient days was 2460 ± 1549 (mean ± standard deviation). Of the 133 patients, there were 16 cases (12.0%) of cardiac re-hospitalization during the 1-year follow-up period. The average step count before discharge was significantly lower in the 16 patients who were re-hospitalized for cardiac causes (1297 ± 1232 versus 2620 ± 1524, $p < 0.01$). The cut-off value that predicted the occurrence of cardiac re-hospitalization on the receiver operating curve was 1308 steps (area under the curve: 0.783, $p < 0.001$, sensitivity: 0.814, specificity: 0.733). Cox proportional hazards analysis revealed that the strongest predictor of cardiac re-hospitalization was a low step count prior to discharge (≤1308 steps, hazard ratio: 7.58; 95% confidence interval: 2.04–28.22).
Conclusions: In-patient step count appears to be a risk factor for cardiac re-hospitalization within the first year following cardiac surgery. Further studies are needed to clarify the clinical significance of step count both preoperatively and following discharge.

Introduction

In Japan, in-patient cardiac rehabilitation programs after cardiac surgery are provided in accordance with the guidelines of the Japanese Circulation Society [1]. In such programs, patients commence sitting out of bed from the first post-operative day, and progress to standing, marching on the spot, walking within their room, and walking in the hospital corridor. The program aims to enable patients to walk independently in the hospital within 4–8 days postoperatively. Consistent with rehabilitation programs after acute myocardial infarction, the program is designed to enable post-operative patients to engage in progressively higher exercise tasks, with increasing exercise load, providing there are no abnormal symptoms or signs during activity, for example changes in electrocardiogram, or abnormal blood pressure and heart rate response. In a multicenter study carried out in Japan, Takahashi et al. [2] found that 78% of cardiac patients who underwent rehabilitation in accordance with these guidelines [1] commenced walking independently within 8 days postoperatively. Although early discharge following cardiac surgery is aimed at reducing costs, the ability of a patient to walk independently as early as possible following surgery and to increase their physical activity by

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walking more steps, should be evaluated separately as these are two distinct criteria in terms of patients' daily activities.

To our knowledge, the relationship between in-patient physical activity after cardiac surgery and post-operative prognosis has not been reported. If a low physical activity following cardiac surgery was predictive of cardiac re-hospitalization within the following year, this could lead to a greater focus in the post-operative rehabilitation program on increasing the amount of daily physical activity undertaken by patients.

The aim of this study was to identify factors related to physical activity, as measured by step count, during the in-patient stay after cardiac surgery, as well as to examine the relationship between the in-patient steps walked and cardiac re-hospitalization in the following year.

Methods

Subjects

A total of 160 patients who underwent cardiac surgery at the Gunma Prefectural Cardiovascular Center consented to participate in this study. Of these 27 (17%) were subsequently withdrawn. Consent was withdrawn by 5 patients, 5 were unable to regain independent walking after surgery, 6 did not wear the activity monitor as required, and 11 patients failed to return the follow-up survey. In total, 133 patients, whose survey responses at 1-year follow-up were available, provided data for this study.

The clinical characteristics of the patients are summarized in Table 1. Forty-one patients received coronary artery bypass grafting (CABG), 77 underwent valve replacement or valvuloplasty, and 15 patients underwent complex surgery such as CABG plus valve replacement. There were 91 males and 42 females, and the mean age was 66.4 years (range 38–84 years).

Post-operative rehabilitation program

The post-operative rehabilitation program was carried out in accordance with the guidelines of the Japanese Circulation Society [1]. In brief, this included daily exercise sessions held in a gym once patients were able to walk independently. These sessions consisted of a 5-min warm-up followed by 20 min of aerobic exercise training. All patients used a cycle ergometer for exercise training. Other than these structured exercise sessions, patients determined their own level of daily physical activity.

Table 1
Clinical characteristics of the 133 patients.

Characteristic	
Age [years; mean (range)]	66.4 (38–84)
Male [*n* (%)]	91 (68.4%)
Type of operation [*n* (%)]	
CABG	41 (30.8%)
Valve replacement or valvuloplasty	77 (57.9%)
Complex surgery	15 (11.3%)
Post-operative day that patient walked independently [mean (range)]	6.4 (2–36)
Length of post-operative stay [mean (range)]	20.1 (10–45)
NYHA heart failure classification before surgery (I/II/III/IV) (*n*)	41/59/27/6
NYHA heart failure classification before discharge (I/II/III/IV) (*n*)	46/82/5/0
Pre-discharge left ventricular ejection fraction [% (range)]	61.3 (16–86)
In-patient steps before discharge [mean (range)]	2460 (249–8215)
Re-hospitalization during 1-year follow-up period [*n* (%)]	16 (12.0%)
Cardiac re-hospitalization [*n* (%)]	
Heart failure	7 (44%)
Arrhythmia (atrial fibrillation)	5 (31%)
Re-operation	1 (6%)
Other	3 (19%)

CABG, coronary artery bypass grafting; NYHA, New York Heart Association.

Step count

The number of steps was measured each day with data collection commencing immediately after patients left the intensive care unit and continued until discharge from hospital. Step count was measured using a waist-mounted triaxial accelerometer (Active Style Pro HJA-350IT, Omron Healthcare, Kyoto, Japan) [3]. This triaxial accelerometer accurately classifies locomotive and household activities from the analysis of both unfiltered and filtered acceleration signals. A single investigator (M.K.) instructed patients in the use of the accelerometer and ensured that it was correctly positioned at the patient's waist in front of the right hip, and that it was working properly. The patients were instructed to wear the monitor throughout the day for a period of at least 8 h. The mean number of steps walked during the last three in-patient days was calculated and used in the analyses. Once patients were able to walk independently, they were free to choose their level of daily activity with the exception of the activity undertaken as part of the structured exercise sessions. Steps walked during the structured exercise sessions were not included in the analyses.

Patients' clinical characteristics

This information was obtained from the medical records. Specifically, age, gender, body mass index (BMI), details of surgery performed, operation time, blood transfusion, results from blood tests comprising pre-discharge C-reactive protein (CRP), estimated glomerular filtration rate (eGFR) and hemoglobin content (Hb), pre-discharge left ventricular ejection fraction (LVEF), presence of the pleural effusion paracentesis, newly developed post-operative atrial fibrillation and ventricular arrhythmia, New York Heart Association heart failure classification before surgery and before discharge, and length of post-operative stay were collected. Health-related quality of life (QoL) and mood were also assessed on the day prior to discharge using the SF-36 [4,5], and the Hospital Anxiety and Depression Scale (HADS) [6–8], respectively.

Assessment of health condition at 1-year follow-up and cardiac re-hospitalization survey

The patients were mailed a survey 1 year after surgery in order to collect data pertaining to their current health condition, and occurrence of cardiac re-hospitalization. A cardiac re-hospitalization was defined as re-hospitalization or re-operation due to cardiac problems, or the development of new cardiovascular disease.

Ethical considerations

This study was approved by Hyogo University of Health Sciences Ethical Review Board (Authorization Number 10003) and the ethics committee of the Gunma Prefectural Cardiovascular Center. All patients gave written, informed consent prior to data collection.

Statistical analysis

A one-way analysis of variance (ANOVA) was performed to compare the number of in-patient steps between the three types of surgery (i.e. CABG, valve replacement or valvuloplasty, and

Table 2
Univariate correlations between in-patient steps at discharge and age, day at which patient walked independently, health-related QoL, mood, and patients' clinical characteristics.

Related factors	*r*	*p*-Value
Age[a]	−0.40	<0.01
Post-operative day that patient walked independently[a]	−0.39	<0.01
HADS anxiety at the time of discharge[b]	−0.20	<0.05
HADS depression at the time of discharge[b]	−0.25	<0.05
SF-36 at the time of discharge		
PF (physical function)[a]	+0.38	<0.01
VT (vitality)[a]	+0.35	<0.01
eGFR at the time of discharge[a]	+0.23	<0.05
Hb at the time of discharge[a]	+0.32	<0.05

QoL, quality of life; HADS, Hospital Anxiety and Depression Scale; SF-36, Medical Outcomes Study 36-Item Short-Form Health Survey; eGFR, estimated glomerular filtration rate; Hb, hemoglobin content.
[a] Pearson's correlation analysis.
[b] Spearman's correlation analysis.

complex surgery). Pearson's correlation analysis was performed to analyze the relationship between the number of in-patient steps and parametric values of patients' clinical characteristics such as age, post-operative day that patient walked independently, SF-36 score, and blood tests. Spearman's rank correlation analysis was also performed to analyze the relationship between the number of in-patient steps and the HADS score.

With regard to the relationship between the number of in-patient steps and re-hospitalization, the patients were grouped according to whether they required cardiac re-hospitalization (+) or did not require cardiac re-hospitalization (−) in the year following surgery, and the groups were compared using an unpaired *t*-test for their clinical characteristics and in-patient step count.

The cut-off value of the average number of steps before discharge that predicted the occurrence of cardiac re-hospitalization was identified through receiver operating characteristic (ROC) curve analysis.

We also carried out Cox proportional hazards analysis with a setting where clinical risk factors found to be related to the occurrence of cardiac re-hospitalization via univariate analysis were incorporated as covariates, in order to calculate the risk ratio of the cut-off value. Finally, we separated the patients into two groups based on the cut-off value of the average number of steps before discharge, and carried out a Kaplan–Meier survival analysis.

Statistical analysis was performed using SPSS (IBM, Tokyo, Japan), and the significance level was defined at $p < 0.05$ for all tests.

Results

The mean [±standard deviation (SD)] number of steps per day before discharge was 2460 ± 1549 (Table 1). There was no significant difference in the number of in-patient steps before discharge in the different surgical groups being 2336 ± 1815 steps (CABG group), 2521 ± 1336 steps (valve replacement or valvuloplasty group), and 2496 ± 1857 steps (complex surgery group e.g. CABG plus valve replacement) ($p = 0.83$).

Table 2 gives the results of the univariate correlational analyses. There was a significant, but weak, inverse correlation between in-patient steps and age, number of days required for the patient to walk independently in the hospital, and with mood. In contrast, significant but weak positive correlations were found between in-patient steps and the SF-36 domains of physical function and vitality, and with eGFR and Hb assessed at the time of discharge (Table 2).

Of the 133 patients, there were 16 cases (12%) of cardiac re-hospitalization during the year following surgery. Of these 16 cases, there were 7 cases (44%) of hospitalization for heart failure, 5 cases (31%) of new occurrence of atrial fibrillation that required catheter ablation ($n = 3$) or pharmacological treatment ($n = 2$), 1 case (6%) of re-operation (surgery for abdominal aortic aneurysm after CABG), and 3 other cases (19%) [takotsubo cardiomyopathy ($n = 1$), thoracic endovascular aneurysm repair after CABG ($n = 1$), re-vascularization after CABG ($n = 1$)] (Table 1). The average number of steps before discharge in the cardiac re-hospitalization (+) group was significantly lower than that of cardiac re-hospitalization (−) group ($p < 0.01$) (Table 3). Further, the group requiring re-hospitalization (+) was significantly older ($p < 0.05$), had lower eGFR ($p < 0.01$), and longer in-patient stay ($p < 0.01$) (Table 3). A total of 9 out of 133 patients participated in the supervised

Table 3
Comparison of clinical characteristics with patients grouped according to cardiac re-hospitalization (+) and no cardiac re-hospitalization (−).

	Cardiac re-hospitalization (+) ($n = 16$)	Cardiac re-hospitalization (−) ($n = 117$)	*p*-Value
Age (years)	71.6 ± 5.6	65.7 ± 9.5	<0.05
Gender (M:F)	9:7	82:35	n.s.
Body mass index	22.6 ± 4.5	22.8 ± 3.9	n.s.
Type of operation [*n* (%)]			
CABG	8 (50.0%)	33 (28.2%)	n.s.
Valve replacement or valvuloplasty	6 (37.5%)	71 (60.7%)	
Complex surgery	2 (12.5%)	13 (11.1%)	
NYHA classification before surgery (I/II/III/IV) (*n*)	4/8/2/2	37/51/25/4	n.s.
NYHA classification before discharge (I/II/III/IV) (*n*)	4/11/1/0	42/71/4/0	n.s.
Operation time (min)	271.0 ± 92.0	264.3 ± 83.0	n.s.
Blood transfusion (autologous/allogeneic/non) (*n*)	13/3/0	107/4/6	n.s.
Post-operative day that patient walked independently	8.3 ± 6.0	6.1 ± 4.6	n.s.
In-patient steps before discharge	1297 ± 1232	2620 ± 1524	<0.01
Length of post-operative stay (days)	24.6 ± 5.1	19.5 ± 5.8	<0.01
Post-operative pleural effusion paracentesis (*n*)	1 (6.3%)	4 (3.4%)	n.s.
Newly developed post-operative atrial fibrillation (*n*)	5 (31.3%)	26 (22.2%)	n.s.
Newly developed post-operative ventricular tachycardia (*n*)	1 (6.3%)	7 (6.0%)	n.s.
CRP at hospital discharge (mg/dl)	1.48 ± 1.57	1.71 ± 1.81	n.s.
eGFR at hospital discharge (ml/min/1.73 m^2)	49.7 ± 17.8	63.8 ± 20.4	<0.01
Hb at hospital discharge (g/dl)	10.7 ± 0.8	11.3 ± 1.5	n.s.
LVEF at hospital discharge (%)	54.7 ± 18.8	58.2 ± 13.4	n.s.
Outpatient programs participation more than once a week [*n* (%)]	1 (6.3%)	8 (6.8%)	n.s.

Numerical data are expressed as mean ± SD.
CABG, coronary artery bypass grafting; NYHA, New York Heart Association; CRP, C-reactive protein; eGFR, estimated glomerular filtration rate; Hb, hemoglobin content; LVEF, left ventricular ejection fraction; n.s., not significant.

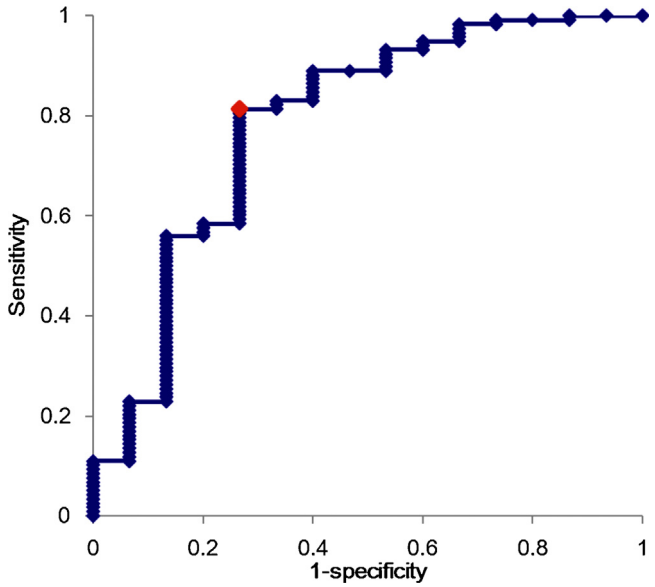

Fig. 1. Receiver operating characteristic (ROC) curve analysis for the occurrence of cardiac re-hospitalization (area under the curve: 0.784, $p < 0.001$, cut-off value >1308 steps, sensitivity: 0.814, specificity: 0.733).

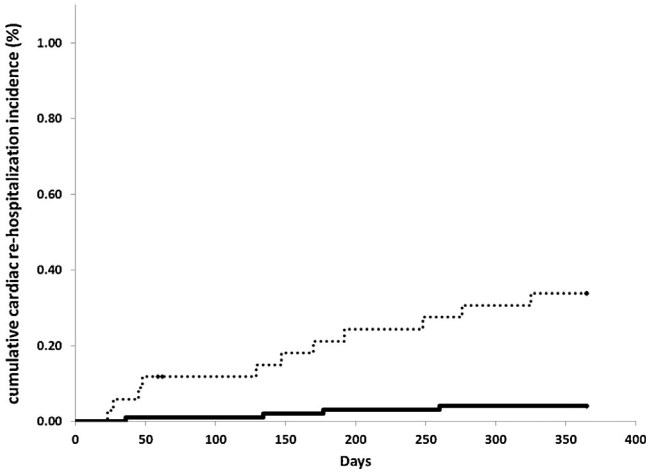

Fig. 2. Kaplan–Meier curves for cumulative cardiac re-hospitalization incidence. Solid and interrupted lines indicate individuals who could or could not walk more than 1308 steps before discharge respectively (log-rank test, $p < 0.0001$).

outpatient cardiac rehabilitation programs and attended more than one supervised session each week. There was no significant difference in the proportion of patients who participated in the supervised outpatient cardiac rehabilitation between the two groups (Table 3).

The cut-off value for the mean number of in-patient steps before discharge that predicted the occurrence of cardiac re-hospitalization on the ROC curve was 1308 steps (area under the curve: 0.784, $p < 0.001$, sensitivity: 0.814, specificity: 0.733) (Fig. 1). Cox proportional hazards analysis, where clinical risk factors of cardiac re-hospitalization including the patient's age, eGFR, and the length of stay were used as covariates, revealed that the strongest predictor of cardiac re-hospitalization to be the condition in which patients were unable to walk 1308 steps or more before discharge (hazard ratio: 7.58; 95% confidence interval: 2.04–28.22) (Table 4).

Finally, the patients were separated into two groups based on in-patient step count (i.e. >1308 steps or ≤1308 steps) for the Kaplan–Meier survival analysis. The results showed that cardiac re-hospitalization occurred significantly more often among the group unable to walk more than 1308 steps before discharge (log-rank test, $p < 0.0001$) (Fig. 2).

Discussion

This study, to the best of our knowledge, is the first to demonstrate that following cardiac surgery physical activity, as measured by daily step count, during the in-patient period is a predictor of the risk of cardiac re-hospitalization in the following year. This finding, however, only applies to the particular setting, i.e. within Japan, where the period of hospitalization after cardiac surgery is longer than in many countries.

Patients who were re-hospitalized due to cardiac problems during the 1-year post-operative follow-up period were older, had a longer length of stay, and eGFR at the time of discharge was significantly lower compared to those who were not re-hospitalized. Poorer renal function in the post-operative period has been shown to be associated with a delayed rate of physical recovery [9,10] and early mortality following cardiac surgery [11].

Following surgery, the majority of patients in this study did not participate in an outpatient cardiac rehabilitation program. Cardiac rehabilitation that includes exercise training has been shown to accelerate the return to normal activities and helps to maintain regular exercise and thus may reduce the proportion of cardiac patients who become sedentary [12,13]. Further, exercise training is expected to prevent the occurrence of atrial fibrillation after cardiac surgery [14]. The onset of atrial fibrillation is also related to the exercise intensity and amount of physical activity [15,16]. A higher level of leisure-time activity and walking have been shown to be associated with graded lower incidence of atrial fibrillation, with progressively lower risk occurring as leisure-time activity and both the distance walked and pace of walking increased [17]. It has also been reported that physical activity in patients with stable coronary heart diseases was most often limited by non-specific symptoms such as shortness of breath, fatigue, and weakness [18]. It is possible that symptoms such as weakness and reduced vitality in part are associated with lower levels of physical activity. Patients who showed lower vitality and less physical activity in our study may have been cautious about engaging in more vigorous exercise after discharge.

Previous studies of patients with cardiovascular disease have reported a significant association between frailty and hospitalizations [19–24]. Low physical activity is one of the major frailty markers [25] and a low number of steps post-operatively can be considered as a marker of physical frailty. In this study, therefore, patients who did not walk more than 1308 steps per day before discharge may have a worse prognosis than patients who walked more than 1308 steps before discharge. The worse prognosis in patients whose number of steps is low during hospitalization may be a result of comorbidities that limited their ability to undertake physical activity, diminished physiological reserve and the capacity to maintain homeostasis [23]. Frail patients may also be less capable of managing their care [21].

We found an inverse correlation between age and in-patients steps, although the correlation was not strong. In addition, patients

Table 4
Cox proportional hazards analysis of predictors of cardiac re-hospitalization.

	Hazard ratio	95% confidence interval	*p*-Value
Step count >1308 before discharge	7.59	2.04–28.22	<0.01
Length of post-operative stay	1.10	1.02–1.19	<0.05
eGFR at hospital discharge	0.99	0.96–1.02	n.s.
Age	1.01	0.95–1.08	n.s.

eGFR, estimated glomerular filtration rate; n.s., not significant.

in the cardiac re-hospitalization (+) group were significantly older compared with the no cardiac re-hospitalization group. This could suggest that age is an important factor related to re-hospitalization. However, Cox proportional hazards analysis revealed that the strongest predictor of cardiac re-hospitalization was the condition in which patients were unable to walk 1308 steps or more before discharge. Although age is undoubtedly an important factor related to poor prognosis, physical frailty as measured by in-patient step count was the strongest predictor of mortality in patients after cardiac surgery in this study.

This study showed that the probability of re-hospitalization to occur in patients whose daily step count was less than 1308 at the time of discharge, could be 7.58 times higher than that of a patient who walked more than 1308 steps. This information is important as it permits the identification of individuals at higher risk of cardiac re-hospitalization, although a daily step count in excess of 1308 steps before discharge was not necessarily indicative of less impairment in overall prognosis.

Our subjects were enrolled from a single local cardiovascular hospital. Therefore, the finding, i.e. 1308 steps before discharge, may be not generalizable to other hospitals as regional and other contextual differences may exist. Therefore, replication of our study in other types of hospital and other areas of the country is necessary to give meaning to the figure of 1308 steps taken pre-discharge. Recent studies also indicate that a low step count in hospitalized older patients is an important predictor of adverse outcome although the patient population and duration of hospitalization both differ from our study [26–28]. Further studies are necessary to develop an optimal level or threshold of daily steps needed to prevent re-hospitalization.

Study limitations

There are several limitations to our study. Although we identified the clinical significance of the amount of in-hospital physical activity, we did not continue to collect step count once patients were discharged. It is well known that low levels of physical activity are associated with several lifestyle-related diseases such as hypertension, cardiovascular disease, and type II diabetes, and both the risk of cardiovascular and all-cause mortality [29–33]. In our study we were unable to elucidate the extent to which the post-discharge physical activity and exercise habits influenced the patient's prognosis including the risk of cardiac re-hospitalization.

Further, it is unknown whether patients whose step count was low during their post-operative period were more inactive prior to surgery as we were unable to collect pre-operative steps. Further study is required in an attempt to elucidate the clinical significance of the amount of physical activity both pre-operatively and following discharge.

Conflict of interest

All authors declare that there is no conflict of interest.

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