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Association of Heart Rate Trajectory Patterns with the Risk of Adverse Outcomes for Acute Heart Failure in a Heart Failure Cohort in Taiwan

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Background: Heart rate trajectory with multiple heart rate measurements is considered to be a more sensitive predictor of outcomes than single heart rate measurements. The association of heart rate trajectory patterns with acute heart failure outcomes has not been well studied. We examined the association of heart rate trajectory patterns with post-discharge outcomes.

Methods: This prospective cohort study was based on an acute heart failure registry in Taiwan. A total of 1509 patients were enrolled in the Taiwan Society of Cardiology – Heart Failure with Reduced Ejection Fraction Registry from May 2013 to October 2015. The outcomes were post-discharge all-cause mortality and heart failure re-admission.

Results: Two heart trajectory patterns were identified in group-based trajectory analysis. One started with a higher heart rate and had an increasing trend over 6 months then a subsequent decline (high-increasing-decreasing group; n = 352; 23.9%). The other started with a lower heart rate and had a relatively stable pattern (low-stable group; n = 1121; 76.1%). Compared with those in the low-stable group, patients in the high-increasing-decreasing group had a higher risk of events (all-cause mortality: hazard ratio 3.10 and 95% confidence interval 1.24-7.77; heart failure re-admission: hazard ratio 1.13 and 95% confidence interval 0.55-2.32).

Conclusion: Patients with a high-increasing-decreasing heart rate trajectory pattern had a higher risk of all-cause mortality than those with a low-stable pattern.

Key Words: Acute heart failure • All-cause mortality • Heart failure hospitalization • Heart rate trajectory

INTRODUCTION

Heart failure is a prevalent and common cause of hospitalization and death worldwide; therefore, it is an important public health issue. Acute heart failure is a unique classification of heart failure because of its worse outcomes and higher complications compared with chronic heart failure. The mortality rate has been reported to be 20%-25% during 1 year for acute heart failure compared to 6% for chronic heart failure.[2,3] Several biomarkers have been identified to estimate the risk of adverse outcomes for patients with heart failure, and heart rate has been proven to be an important risk factor, especially for chronic heart failure.[4,5] However, the influence of heart rate on acute heart failure is still unclear.[4-7] Some studies have reported an association between a higher discharge heart rate and adverse outcomes within 30 days,[8-10] whereas other studies have reported that heart rate reduction, not discharge heart rate itself, was related to outcomes.[11] This inconsistency

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requires further clarification in a longitudinal study.

Moreover, most heart rate studies have been based on a single-point measurement of heart rate, such as the admission or discharge heart rate.[6-9] The major drawback of this measurement is the possibility of dramatic changes in heart rate between examinations. A few studies have used changes in heart rate as a biomarker, and shown that it is a more sensitive predictor of outcome than single-point heart rate measurements.[10,11] The conventional approach to heart rate changes is to measure the difference in heart rate between visits. Chen and colleagues used heart rate trajectories as a biomarker, and found that trajectories could predict carotid stiffness.[12] The trajectories were derived from the group-based trajectory model (GBTM) which combines heart rate values at every measurement point and their change with time.[13,14] The GBTM of heart rate can reveal changes in heart rate with time and identify heterogeneous heart rate trajectories, which cannot be achieved with the conventional approach. To the best of our knowledge, this is the first study to use heart rate trajectory patterns as predictors of adverse outcomes for acute heart failure. This study aimed to examine the association of trajectory patterns of heart rate with post-discharge outcomes.

METHODS

Study design and setting

Our study population was based on the Taiwan Society of Cardiology – Heart Failure with Reduced Ejection Fraction Registry, which is a prospective cohort study of patients referred to 21 medical centers or hospitals in Taiwan. All patients provided informed consent, and the study protocol conformed to the Declaration of Helsinki guidelines. The Institutional Review Boards of all participating hospitals approved this study. The flow diagram is shown in Figure 1. The earliest enrollment of patients started in May 2013, and the clinical outcomes were monitored until October 2015.

Participants

The inclusion criteria were an age older than 18 years, and presenting with either acute new-onset heart failure or acute decompensation of chronic heart failure or presenting with typical heart failure symptoms and signs severe enough to fulfill the criteria of admission. The New York Heart Association (NYHA) functional classification was used to evaluate heart failure severity. Additionally, all patients underwent echocardiography or left ventriculography, but only those who had a left ventricular ejection fraction (LVEF) < 40% were recruited. Patients were regularly followed-up in the outpatient department at 6 and 12 months after discharge. Conditions were checked by a telephone interview for the patients who could not travel to the outpatient department.

Clinical data

Clinical data were collected and documented by research assistants or trained nurses. On admission, information such as history of hypertension, dyslipidemia, diabetes mellitus (DM), stroke, coronary artery disease (CAD), and chronic kidney disease were collected. Smoking and alcohol drinking data were also collected through the patients' medical history. The patients were classified as being current smokers or non-smokers, and as regular drinkers or non-drinkers. Body mass index (BMI) was calculated as weight (kg)/height^2 (m^2). DM was defined as fasting glucose ≥ 126 mg/dL or the use of oral hypoglycemic or insulin medications.

A physical examination was performed by trained physicians or nurses to assess the NYHA functional class, diastolic blood pressure, systolic blood pressure, and

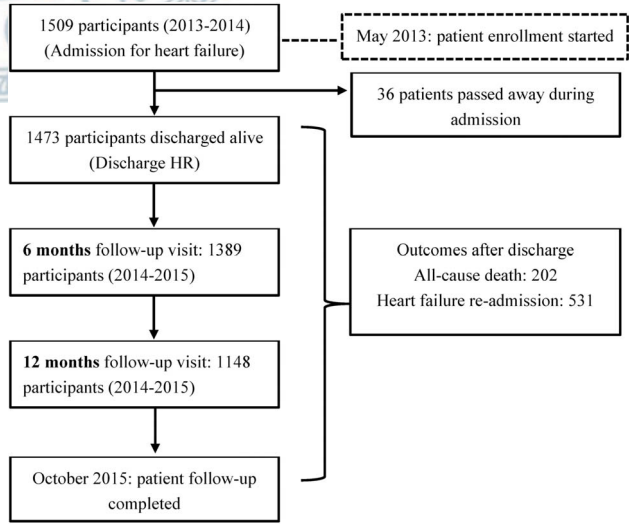

Figure 1. *Flow diagram of the Taiwan Society of Cardiology – Heart Failure with Reduced Ejection Fraction Registry. HR, heart rate.*

heart rate at admission, at discharge, and at the 6- and 12-month follow-up visits. Heart rate was measured by either electrocardiography or physical examinations performed by experienced nurses. Biochemistry data such as serum creatinine (Cre), troponin I, hemoglobin (Hb), and plasma B-type natriuretic peptide (BNP) were obtained at discharge, and at the 6- and 12-month follow-up visits.

Heart rate parameters

The discharge heart rate was defined as the heart rate recorded just before discharge. Two post-discharge follow-up heart rate measurements were recorded at the 6- and 12-month follow-up visits. The GBTM of heart rate was based on combined discharge and post-discharge heart rates, and individuals with similar heart rate pattern changes were grouped together.

Outcomes

After the patients were discharged from hospital, we investigated all-cause mortality or heart failure readmission using telephone interviews or mailed questionnaires. We used discharge heart rate and the GBTM of heart rate to explore their relationships with post-discharge outcomes.

Statistical analysis

For descriptive data, continuous variables were described as mean (± standard deviation); categorical variables were expressed as numbers and percentages. Characteristics of demographic data across groups were compared using analysis of variance for continuous variables and the chi-square test.

Discharge heart rates were modeled as categorical variables and divided into four groups according to the interquartile range. The adjusted covariates included age, sex, blood pressure, NYHA class, BNP, Cre, troponin I, LVEF, rhythm, antihypertensive medications, and history of smoking, alcohol, diabetes, dyslipidemia, and CAD.

GBTM analysis was used to identify trajectory patterns of long-term heart rate changes. SAS 9.4 with the *traj* package (SAS Institute, Cary, NC) was used for this purpose. Group-based modeling assumed that the population was composed of finite distinct groups and involved a procedure to gather individuals with statistically similar trajectories into groups. The key decision to identify trajectory groups in a population was made by determining the number of groups and best fitted shapes of the trajectories. We initially assumed the trajectory patterns to be cubic, and repeated trajectory analysis by changing the number of groups from two to four. The Bayesian information criterion (BIC) was used to initially estimate the appropriate number of trajectory patterns. The number of groups with the highest BIC was considered to be the best fitted model.[13-15] BICs for two, three and four groups were -14746, -14705, and -14670 respectively. However, BIC was not the only criteria for grouping. Other criteria included an adequate sample number in each group (at least > 5%) and small and not overlapping confidence interval was favored.[13-15] However, there were a small number of members (< 2%) in three and four groups.[13-15] Moreover, there are wide and overlapping confidence intervals between members in four groups.[13-15] Therefore, a two-group model was chosen after considering all of these factors.

After identifying the number of groups, different shapes for the trajectories (linear, quadratic, cubic, etc.) were tested in the next step. We reduced the polynomial orders until the highest polynomial order for each group was significant at a confidence level alpha of 0.05. The two-group model with quadratic trajectories was identified through these steps.[13-15]

Missing data are often a problem in longitudinal studies. We tested the null hypothesis that the missing data were completely at random using Little's test. Subjects with missing data were included in the analysis, but only available data for each subject were used. We included the patients with only one single heart rate measurement at discharge, and 255 patients were identified. These patients were classified into the high-increasing-decreasing group if the heart rate was higher than about 90 beats per minute, and into the low-stable group if the heart rate was lower than about 80 beats per minute.

Survival curves were calculated using the Kaplan-Meier method. In Cox regression analyses, adjusted hazard ratios were estimated for outcomes related to all types of heart rate parameters. Statistical significance was defined as a two-tailed $p < 0.05$. All analyses were performed using SAS version 9.4 (SAS Institute).

RESULTS

Figure 1 demonstrates the available heart rate data recorded at discharge and the number of outcomes at different stages of heart failure. Table 1 shows the baseline characteristics of the patients with acute heart failure sub-grouped by the interquartile range of discharge heart rate. Group 1 (n = 384) comprised participants with heart rates ≤ 70 beats per minute (bpm); group 2 (n = 362) comprised those with heart rates between 71 and 80 bpm; group 3 (n = 366) comprised those with heart rates between 81 and 90 bpm; and group 4 (n = 346) comprised those with heart rates ≥ 91 bpm. Group 4 participants tended to be younger and had a shorter history of dyslipidemia, lower beta-blocker usage, lower LVEF, and lower frequency of atrial fibrillation and flutter than the participants in the other groups.

Two quadratic trajectories of heart rate derived from GBTMs are shown in Figure 2. We labeled them according to the discharge heart rate, followed by the increasing or decreasing pattern: group 1 (low-stable pattern; n = 1121; 76.1%), and group 2 (high-increasing-decreasing; n = 352; 23.9%). The low-stable group was characterized by a low starting discharge heart rate of 77 bpm that gradually decreased to 75 bpm at 6 months and then gradually increased to 76 bpm at 12 months.

Table 1. Baseline characteristics of patients sub-grouped according to the interquartile range of the discharge heart rate

N (%)/mean (SD)	Group 1 (discharge HR ≤ 70) (n = 384)	Group 2 (71 ≤ discharge HR ≤ 80) (n = 362)	Group 3 (81 ≤ discharge HR ≤ 90) (n = 366)	Group 4 (discharge HR ≥ 91) (n = 346)	p-value
Age (year)	65.3 (16.0)	65.6 (15.4)	62.4 (15.4)	59.1 (17.3)	< 0.001
Sex (woman)	108 (28.1%)	103 (28.5%)	98 (26.8%)	96 (27.8%)	0.96
BMI	25.1 (4.76)	25.2 (5.23)	24.9 (5.02)	25.9 (7.44)	0.08
Smoking	190 (49.5%)	176 (48.6%)	197 (53.8%)	175 (50.6%)	0.52
Alcohol	129 (33.6%)	132 (36.5%)	133 (36.3%)	108 (31.2%)	0.40
History of diabetes	149 (38.8%)	152 (42.0%)	172 (47.0%)	163 (47.1%)	0.06
History of dyslipidemia	83 (21.6%)	103 (28.5%)	73 (20.0%)	70 (20.2%)	0.019
History of CAD	166 (43.2%)	159 (43.9%)	156 (42.6%)	122 (35.3%)	0.07
Medications					
ACEI or ARB	247 (64.3%)	219 (60.8%)	221 (60.9%)	207 (60.9%)	0.70
Beta-blocker	253 (65.9%)	222 (61.7%)	214 (59.0%)	174 (51.2%)	0.001
Diuretics	320 (83.3%)	282 (78.3%)	307 (84.6%)	282 (82.9%)	0.14
Digoxin	93 (24.2%)	84 (23.3%)	100 (27.6%)	102 (30%)	0.16
Nitrates	145 (37.8%)	133 (36.9%)	130 (35.8%)	115 (33.8%)	0.72
Hydralazine	25 (6.51%)	14 (3.9%)	17 (4.68%)	15 (4.41%)	0.37
BNP (pg/mL)	1757.3 (1588.2)	1600.5 (1352.4)	1702.1 (1530.3)	1737.1 (1632.2)	0.85
Hb (g/dL)	12.4 (2.4)	11.5 (2.2)	12.1 (2.5)	12.2 (2.4)	0.008
Cre (mg/dL)	2.1 (5.0)	1.8 (2.0)	1.7 (1.5)	1.5 (1.5)	0.28
BUN (mg/dL)	34.6 (23.0)	35.5 (26.5)	33.1 (23.7)	32 (22.1)	0.44
NYHA Class					0.97
Classes 1 and 2	274 (71.4%)	266 (73.5%)	270 (73.8%)	252 (72.8%)	
Class 3	88 (22.9%)	80 (22.1%)	80 (21.9%)	79 (22.8%)	
Class 4	22 (5.73%)	16 (4.42%)	16 (4.37%)	15 (4.34%)	
LVEF (%)	32.6 (9.64)	31.0 (9.47)	32.4 (10.6)	29.49 (11.0)	0.010
Troponin I (ng/mL)	3.27 (13.5)	2.02 (8.97)	1.54 (7.82)	2.89 (14.8)	0.31
Rhythm					0.006
Sinus	215 (59.4%)	230 (67.7%)	232 (67.4%)	239 (74.0%)	
Atrial fibrillation or atrial flutter	126 (34.81%)	97 (28.5%)	96 (27.9%)	69 (21.4%)	
Paced	21 (5.8%)	13 (3.82%)	16 (4.65%)	15 (4.64%)	

ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BMI, body mass index; BNP, brain natriuretic peptide; BUN, blood urea nitrogen; CAD, coronary artery disease; Cre, creatinine; Hb, hemoglobin; HR, heart rate; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; SD, standard deviation.

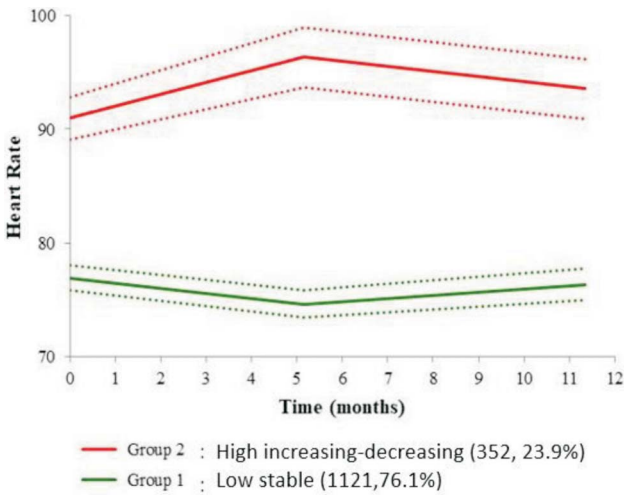

Figure 2. *Heart rate sub-grouped according to the group-based trajectory model.*

The high-increasing-decreasing group was characterized by a high starting discharge heart rate of 91 bpm that gradually increased to 96 bpm at 5 months and then gradually decreased to 94 bpm at 12 months.

Demographic data and descriptive analysis based on the subgroups of GBTM of the heart rate are presented in Table 2. The participants in the high-increasing-decreasing group tended to be younger, were predominantly male, had higher BMI, and had a lower frequency of atrial fibrillation. In addition, fewer of these patients used beta-blockers, digoxin, and hydralazine than those in the low-stable group.

Kaplan-Meier survival curves for outcomes according to the quartiles of discharge heart rate and trajectories of heart rate are shown in Figures 3-4. For the discharge heart rate, the log-rank test was significant for

Table 2. Baseline characteristics of patients sub-grouped according to the GBTM of the heart rate

	Group 1 (Low-stable) (n = 1,121)	Group 2 (High-increasing-decreasing) (n = 352)	p-value
Age (year)	64.8 ± 15.6	58.2 ± 17.1	< 0.001
Sex (female)	330 (29.4%)	79 (22.4%)	0.011
BMI (kg/m^2)	25.0 ± 4.87	26.2 ± 7.65	0.009
Smoking	552 (49.2%)	193 (54.8%)	0.07
Alcohol	379 (33.8%)	125 (35.5%)	0.56
History of diabetes	481 (42.9%)	161 (45.7%)	0.35
History of dyslipidemia	255 (22.8%)	76 (21.6%)	0.65
History of CAD	482 (43%)	132 (37.5%)	0.07
Medications			
ACEI or ARB	674 (60.6%)	228 (65.3%)	0.11
β-blocker	688 (61.8%)	184 (52.7%)	0.003
Diuretics	915 (82.2%)	287 (82.2%)	0.99
Digoxin	271 (24.4%)	108 (31.0%)	0.014
Nitrates	414 (37.2%)	116 (33.2%)	0.18
Hydralazine	61 (5.48%)	10 (2.87%)	0.047
BNP (pg/mL)	1736.1 ± 1565.6	1473.0 ± 1190.5	0.09
Hb (g/dL)	12.0 ± 2.31	12.3 ± 2.61	0.08
Cre (mg/dL)	1.84 ± 3.29	1.63 ± 1.67	0.36
NYHA Class			0.09
Classes 1 and 2	804 (71.7%)	264 (75%)	
Class 3	257 (22.9%)	79 (22.4%)	
Class 4	60 (5.35%)	9 (2.56%)	
LVEF (%)	31.8 ± 10.1	30.2 ± 10.6	0.07
Troponin I (ng/mL)	2.17 ± 10.5	3.4 ± 14.5	0.27
Rhythm			0.003
Sinus	680 (64.7%)	246 (74.3%)	
Atrial fibrillation or atrial flutter	315 (30.0%)	76 (23.0%)	
Paced	56 (5.33%)	9 (2.72%)	

ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BMI, body mass index; BNP, brain natriuretic peptide; CAD, coronary artery disease; Cre, creatinine; DM, diabetes mellitus; GBTM, group-based trajectory model; Hb, hemoglobin; HR, heart rate; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association.

heart failure re-admission (p = 0.013) but not for all-cause mortality (p = 0.72). For the trajectories of heart rate, the high-increasing-decreasing group had worse outcomes than the low-stable group, and the log-rank test results for all-cause mortality and heart failure re-admission between these two groups were significant (p = 0.019 and 0.008, respectively).

Associations of discharge heart rate and GBTM of heart rate with the post-discharge outcomes are shown in Table 3. For discharge heart rate, the adjusted hazard ratios of all-cause mortality and heart failure re-admission for the participants in group 4 compared with those for the participants in group 1 were 0.98 [95% confidence interval (CI), 0.33-2.91; p = 0.88] and 0.80 (95%

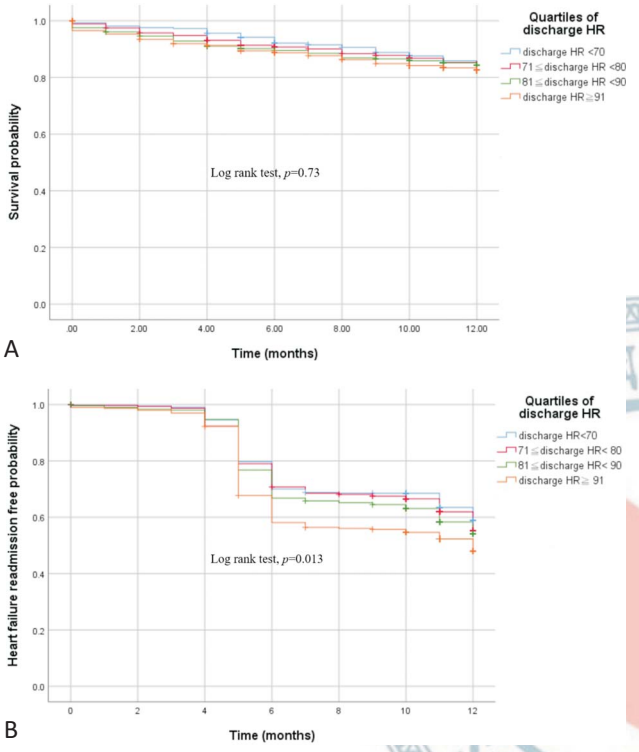

Figure 3. *Survival curve based on the admission or discharge heart rate. (A) Kaplan-Meier curves: quartiles for discharge heart rate (all-cause mortality). (B) Kaplan-Meier curves: quartiles for discharge heart rate (heart failure re-admission).*

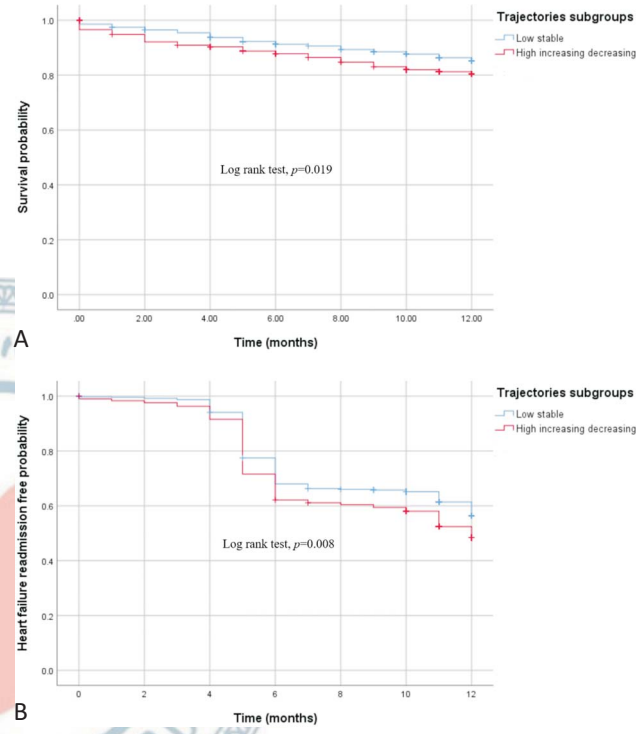

Figure 4. *Survival curve based on the group-based trajectory model (GBTM) of the heart rate. (A) Kaplan-Meier curves: trajectories of the heart rate (all-cause mortality). (B) Kaplan-Meier curves: trajectories the heart rate (heart failure re-admission).*

Table 3. Discharge heart rate, trajectories of the heart rate, and hazard ratio and 95% confidence interval for post-discharge all-cause mortality and heart failure re-admission

	All-cause mortality	p value	Heart failure re-admission	p value
Events	202		531	
Adjusted hazard ratio (95% CI)				
Discharge HR (categorical)				
(Group 2/Group 1)	0.48 (0.18-1.30)	0.15	0.64 (0.30-1.37)	0.25
(Group 3/Group 1)	0.51 (0.14-1.84)	0.30	0.72 (0.31-1.66)	0.44
(Group 4/Group 1)	0.98 (0.33-2.91)	0.97	0.80 (0.34-1.87)	0.60
Trajectories of HR (high-increasing-decreasing/low-stable)	3.10 (1.24-7.77)	0.016	1.13 (0.55-2.32)	0.75

CI, confidence interval; HR, heart rate.

Covariates: age, sex, blood pressure, New York Heart Association functional class, left ventricular ejection fraction, brain natriuretic peptide, creatinine, troponin I, rhythm, antihypertensive medications, and history of smoking, alcohol, diabetes, dyslipidemia, and coronary artery disease.

CI, 0.34-1.87; p = 0.60), respectively. For GBTM of the discharge heart rate, the adjusted hazard ratios of all-cause mortality and heart failure re-admission for the participants in the high-increasing-decreasing group compared with those in the low-stable trajectory group were 3.10 (95% CI, 1.23-7.77; p = 0.016) and 1.13 (95% CI, 0.55-2.32; p = 0.75), respectively (Table 3).

To compare the trajectories with single-point measurement of heart rate, we dichotomized the patients into those with a lower discharge heart rate versus those with a higher discharge heart rate by the median of the discharge heart rate. Table 4 shows the hazard ratios of all-cause mortality and heart failure re-admission for the patients with a higher discharge heart rate compared to those with a lower discharge heart rate: 1.03 (95% CI, 0.43-2.47; p = 0.96) and 0.94 (95% CI, 0.50-1.77; p = 0.85), respectively.

DISCUSSION

Our findings showed that the heart rate trajectory patterns were heterogeneous in the patients with acute heart failure. The GBTM did not assume a specific form of heart rate change in advance, but it identified trajectory patterns learned from the data.[13-15] The heart rate trajectory patterns were based on the combination of heart rate at discharge, follow-up heart rate, and time; therefore, the results were not easily biased by only one heart rate observation. Determining the risk of all-cause mortality from the baseline heart rate is sometimes arbitrary, particularly when the heart rate change or variation with time is high. In this study, the GBTM demonstrated high-increasing-decreasing and low-stable patterns. The findings showed that most of our study patients followed these two trajectories. The results did not deny the existence of other trajectories such as high-stable, low-increasing, etc., but the number of those trajectories was relatively small and were integrated into low-stable or high-increasing patterns.

A previous study showed that higher discharge heart rates were associated with increased risks of death and heart failure re-admission, especially during the first 30 days after discharge.[8] Our study did not show any correlation between single discharge heart rate measurements and adverse outcomes. In addition to single discharge heart rate measurements, we analyzed the trajectory pattern of heart rate, which combined discharge heart rate with 6-month and 12-month post-discharge heart rate measurements. Compared with single discharge heart rate measurements, the trajectory patterns of the combined heart rate measurements during 1 year showed significant associations with all-cause mortality after discharge. This finding showed that the trajectories were more sensitive predictors, especially for all-cause mortality. The patients discharged with higher heart rates and lacking early heart rate control leading to heart rate increases within 5-6 months had worse adverse outcomes compared to those discharged with lower heart rates and stable heart rates. Higher discharge heart rates and increasing heart rates are more likely to reflect a poor in-hospital treatment program, advanced status of heart failure, inadequate medical control before discharge, or poor compliance with medical control, all of which can lead to early death.[16-20]

Although measuring the heart rate is convenient and inexpensive, heart rate is an underrated vital sign parameter. Many acute heart failure patients are discharged from hospital without appropriate heart rate control,[17,18] and this has been correlated with the suboptimal practice of guideline-directed therapy and a high heart failure re-hospitalization rate.[19-22]

Although the external validity of our study was not tested, our results highlight the possible benefits of investigating heart rate not only using a single-point measurement but also using trajectory patterns. Moreover,

Table 4. Higher and lower discharge heart rates and hazard ratio and 95% confidence interval of post-discharge outcomes

	All-cause mortality	p value	Heart failure re-admission	p value
Discharge HR (categorical) (higher/lower discharge heart rate)*	1.03 (0.43-2.47)	0.96	0.94 (0.50-1.77)	0.85

Covariates: age, sex, blood pressure, New York Heart Association functional class, left ventricular ejection fraction, brain natriuretic peptide, creatinine, troponin I, rhythm, antihypertensive medications, and history of smoking, alcohol, diabetes, dyslipidemia, and coronary artery disease.

* Heart rates were categorized into higher or lower group based on the median of the discharge heart rate.

this study demonstrated the utility of repeated heart rate measurements through the use of heart rate trajectory patterns. Considering our heart rate trajectory pattern findings, both maintaining a discharge heart rate lower than 90 bpm and also controlling the heart rate within 5-6 months appear to be important to avoid adverse outcomes of heart failure.

This study has several limitations. First, heart rate data were not completely based on electrocardiography, especially the admission heart rate data. Some of these data were based on physical examinations performed in the emergency department. Second, heart rate measurements were not completely based on sinus rhythm. We did not exclude patients with atrial fibrillation or pacemaker rhythm because of the limited number of participants. The effects of heart rate on outcomes may vary for patients with sinus rhythm and atrial fibrillation. Third, some new heart failure medications such as ivabradine or valsartan/sacubitril were not available when the trial was ongoing. These medications comprise the current standard guideline-directed medical therapy for heart failure patients and have been shown to have a close relationship with outcomes.[23,24] Fourth, some important confounders were not adjusted and may have biased our results. These residual confounders included the severity of coronary artery diseases, results of revascularization, physical activity, diet, thyroid function, alcohol consumption, and pregnancy.[25,26] In addition, several cofounders would vary with time, but we did not adjust them accordingly. Finally, we recognize that those with just one heart rate measurement would bias the results of trajectories and would be a major limitation. However, due to the limited number of patients, we did not exclude these participants. Further studies with more participants and repeated heart rate measurement are required to prove the validity of heart rate trajectories.

CONCLUSIONS

This study demonstrated the importance of identifying specific trajectory patterns of heart rate and elucidated their associations with all-cause mortality for acute heart failure patients. Our results suggest that those with a higher discharge heart rate (> 90 bpm) combined with an increasing trend in the following 6 months that then gradually decreased had a higher all-cause mortality rate than those with a lower discharge heart rate (< 80 bpm) combined with a stable heart rate pattern.

CONFLICT OF INTEREST

All the authors declare no conflict of interest.

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