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Efficacy in predicting mortality of patients with heart failure using heart rate before intensive care unit discharge: a retrospective cohort study from MIMIC-IV Database

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ABSTRACT

Objective Heart rate serves as a critical prognostic factor in heart failure (HF) patients. We hypothesise that elevated heart rate in critically ill HF patients on discharge from the intensive care unit (ICU) could be linked to adverse outcomes.

Design A single-centre retrospective cohort study.

Setting This study used data collected between 2008 and 2019 from the Medical Information Mart for Intensive Care IV (V.2.0) Database.

Participants From the 76 943 ICU stays, we enrolled 2365 patients in this study.

Primary and secondary outcome measures We observed correlations between in-hospital mortality and ICU discharge heart rate of 83.56±15.81 beats per minute (bpm) (survivors) vs 93.84±17.28 bpm (non-survivors, p<0.001). Total mortality showed similar trends, with 83.67±15.36 bpm (survivors) vs 85.23±17.25 bpm (non-survivors, p=0.027), as did ICU readmissions at 83.55±15.77 bpm (non-readmitted) vs 88.64±17.49 bpm (readmitted, p<0.001).

Results Given multivariate analysis, the ICU discharge heart rate strongly predicted in-hospital mortality (HR 1.032 (95% CI 1.022 to 1.041), p<0.001), total mortality (HR 1.008 (95% CI 1.004 to 1.013), p<0.001) and ICU readmission (HR 1.018 (95% CI 1.010 to 1.025), p<0.001). Patients with an ICU discharge heart rate>90 bpm demonstrated significantly higher in-hospital mortality (HR 2.639 (95% CI 1.898 to 3.669), p<0.001), total mortality (HR 1.342 (95% CI 1.163 to 1.550), p<0.001) and ICU readmission rates (HR 1.781 (95% CI 1.413 to 2.243), p<0.001).

Conclusion The findings suggest that HF patients with an elevated heart rate (>90 bpm) at ICU discharge are more likely to experience increased in-hospital mortality, total mortality and ICU readmissions, indicating potential negative outcomes.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The cohort comprised of a large and extensive coverage of 'real-world' intensive care unit (ICU) cases.
⇒ Lack of detailed information on medications and echocardiography.
⇒ Since this study employed an observational data, we could only study the general mortality rate and not particular causes of death.

INTRODUCTION

Heart rate is related to disease and stress, and the maximum heart rate is an indicator of short-term mortality in critical illness.[1] A heart rate≥90 beats per minute (bpm) at the time of multiple organ dysfunction diagnosis is an independent risk factor for increased 28-day mortality.[1] Patients with a sustained heart rate>95 bpm for over 12 hours during any 24-hour period in the intensive care unit (ICU) experienced a higher incidence of major cardiac events and longer ICU stays[2]

Heart failure (HF) and ICU

According to the Romanian Acute Heart Failure Syndromes registry, 10.7% of patients with the condition required ICU care, with admission to the ICU being linked to an increased risk of in-hospital mortality (17.3% vs 6.5%, p=0.002).[3] Within a Taiwan national database of 192 201 patients who were admitted to the ICU, a total of 25 263 (13.14%) patients were readmitted. HF was identified as a significant risk factor for readmission to the ICU (HR 3.365 (95% CI 3.047 to 3.717), p≤0.001).[4]

Heart rate and HF

Higher heart rate was related to the development of regional and global left ventricular (LV) dysfunction independent of subclinical atherosclerosis and coronary heart disease.[5] In the Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients with Heart Failure (OPTIMIZE-HF) study, the mean heart rate was 87±21.5 bpm in survivors and 89±22.7 bpm in non-survivors during hospitalisation. Multivariable analysis showed that every 10 bpm increase in heart rate, between 65 and 110 bpm, was associated with higher in-hospital mortality (OR 1.094 (95% CI 1.062 to 1.127), p<0.0001).[6] In the Get With the Guidelines-Heart Failure (GWTG-HF) study, in-hospital mortality risk is calculated by summing points assigned to each predictor variable, with a total score ranging from 0 to 100. Heart rate is one of these factors: a rate of 79 bpm or below is assigned 0 points, while a rate of 105 bpm or higher is assigned 8 points.[7]

In 2001, the Cardiac Insufficiency Bisoprolol Study II (CIBIS II) trial demonstrated that heart rate can not only function as an indirect marker of disease but may also directly contribute to the development of HF.[8] The Systolic Heart failure Treatment with the IF Inhibitor Ivabradine Trial (SHIFT) trial showed that ivabradine treatment helps systolic HF patients with sinus rhythm and a heart rate of ≥70 bpm.[9] In patients with worsening HF, the first hospital admissions were lower in the group with the lowest heart rate (70 to <72 bpm) compared with those with the highest baseline heart rate (≥87 bpm). In the placebo group, patients with a heart rate ≥87 bpm had more than double the risk of cardiovascular death or hospital admission for worsening HF compared with those with the lowest heart rate (HR 2.34, 95% CI 1.84 to 2.98, p<0.001). Event rates increased by 3% for every 1 bpm rise from baseline and by 16% for every 5 bpm increase.[10] Ivabradine treatment is associated with reduced risks of cardiovascular mortality, all-cause mortality and HF rehospitalisation within 1 year among patients with acute decompensated HF with reduced ejection fraction (HFrEF) in real-world populations.[11] Among patients with HFrEF, ivabradine treatment had a more notable benefit on haemodynamic stability.[12]

Limitations of previous studies

Based on the aforementioned information, we summarise the following key points. First, heart rhythm plays a crucial role as an important prognostic factor in patients with HF. Second, pharmacological management aimed at controlling the heart rhythm in hospitalised HF patients holds the potential to improve their prognosis. Third, it has been observed that over 10% of patients hospitalised with acute HF require intensive care, and they have a higher mortality rate. However, there is currently a lack of relevant studies investigating the association between post-treatment heart rhythm control in critically ill HF patients on transfer from the ICU and their future clinical outcomes.

Aims of the current study

Our objective in the present study is to address this research gap by exploring the relationship between the heart rate before ICU discharge and mortality in HF patients with the Medical Information Mart for Intensive Care IV (MIMIC IV) Database, thereby providing a more comprehensive understanding and guidance for clinical practice.

METHODS

Patient and public involvement

Patients and the public were not directly involved in either the design or the implementation of this study, as it relied on previously collected data.

Data source

This cohort study was conducted using data from the MIMIC-IV V.2.0 Database, which was collected between 2008 and 2019.[13,14] MIMIC-IV is a publicly available and real-world clinical database that was maintained by the Beth Israel Deaconess Medical Center during the same period. It includes records of over 200 000 emergency department admissions and over 60 000 ICU stays. One author, M-IS, has finished the Collaborative Institutional Training Initiative examination (certification number: 42188048) and achieved access to the database for data extraction. The code for extracting data can be found on GitHub (https://github.com/MIT-LCP/mimic-iv).[15]

Eligibility criteria

Our study included only adult patients who were admitted to the ICU due to HF and older than 18 years. The diagnosis of HF was determined using the International Classification of Diseases, 10th Revision, and the following codes were considered: I500, I501, I509, I110, I130 and I132. In cases where a patient was admitted to the ICU multiple times, only data from the first ICU stay were included. We eliminated from our analysis the patients who were discharged from the ICU within 24 hours and those with missing data for vital signs such as blood pressure and heart rate within 24 hours before discharge (figure 1).

Definitions of heart rate and outcomes measures

The ICU discharge heart rate was defined as the last heart rate before discharge from the ICU, and the average ICU discharge heart rate was defined as the 24-hour average heart rate before discharge from the ICU. The primary outcomes were in-hospital mortality and total mortality. The total mortality was populated from state death records. The secondary outcome was ICU readmission in the same hospitalisation. ICU readmission was defined as when a patient was readmitted to the ICU after an interval of more than 8 hours since the previous discharge from the ICU.

Demographic and clinical characteristics

In our study, we included demographic and clinical characteristics recorded in the ICU. We also calculated various scores within the first 24 hours of ICU admission and vital signs such as heart rate, blood pressure, respiratory rate, SpO_2, urine output and serum creatinine were extracted throughout the entire ICU stay (table 1). These covariates, which included basic demographic information and

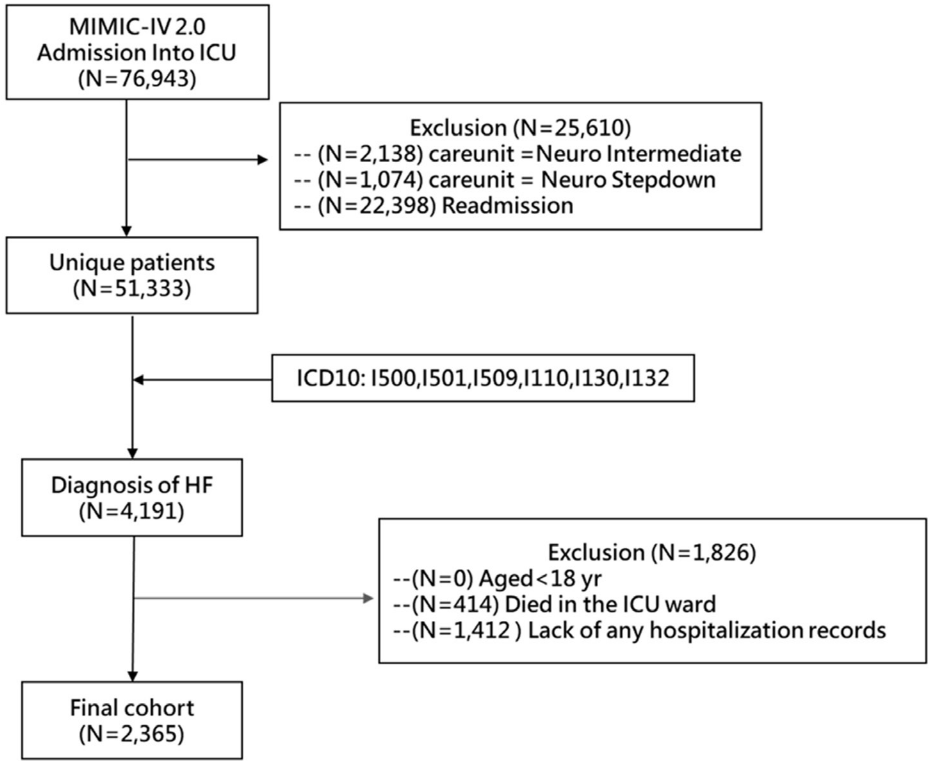

Figure 1 Study flowchart. ICD-10, International Classification of Diseases, 10th Revision; ICU, intensive care unit; MIMIC-IV, Medical Information Mart for Intensive Care IV.

clinical characteristics of patients, were chosen based on previous related studies.

Statistical analysis

Continuous variables are expressed as the mean and SD. Categorical variables are presented as the number and percentage (%). The χ^2 test or Fisher's exact test was used to test comparisons between groups for categorical variables, whereas the t test was used for comparisons of continuous variables as appropriate. We used receiver operating characteristic (ROC) curves to identify the last heart rate before leaving the ICU cut-off values for each study outcome. Cox regression analysis was conducted to assess the association between heart rate and outcomes, with the results expressed as HR and corresponding 95% CIs. Kaplan-Meier survival curves were produced for three outcomes: in-hospital mortality, total mortality and ICU readmission. All analyses were performed in R (V.4.2.3) and SPSS (V.20). A threshold of p<0.05 (two sided) was considered statistically significant.

RESULTS

Study population

Considering the 76 943 admissions registered in the ICU, we enrolled 2365 adult HF patients in this study (table 1). During the follow-up period of 140.26±246.02 days, the average length of ICU stay was 4.49±5.10 days and the mean duration of total hospital stay was 13.91±12.44 days. The female proportion was 40.47% (n=957), the mean age of the study population was 69.7±12.69 years and the body mass index (BMI) was 29.83±8.31 kg/m^2. The mean heart rate during admission to the ICU was 87.66±20.46 bpm, the mean ICU discharge heart rate was 84.26±16.12 bpm and the mean 24-hour average ICU discharge heart rate was 83.82±14.49 bpm. The underlying diseases of the enrolled population included myocardial infarction (40.13%, n=949), cerebrovascular disease (14.25%, n=337) and diabetes mellitus (47.15%, n=1115).

Patient follow-up

The in-hospital mortality was 6.81% (n=161), total mortality was 37.76% (n=893) and the ICU readmission rate was 14.04% (n=332). In terms of in-hospital/total mortality and ICU readmission, no significant difference was observed across the sexes. Patients who were younger and had a lower BMI demonstrated a lower rate of in-hospital mortality (p=0.001) and total mortality (p<0.001) (table 2). The in-hospital mortality, total mortality and ICU readmission were all related to lower ICU discharge heart rate, 24-hour average ICU discharge heart rate and ICU admission heart rate. Regarding the outcome of in-hospital mortality, the ICU discharge heart rate was 83.56±15.81 bpm (survival) vs 93.84±17.28 bpm (dead) (p<0.001), and the 24-hour average ICU discharge heart rate was 83.20±14.29 bpm (survival) vs 92.41±14.55 bpm (dead) (p<0.001). Regarding the outcome of total mortality, the ICU discharge heart rate was 83.67±15.36 bpm (survival) vs 85.23±17.25 bpm

Table 1 Baseline characteristics

Variable	All patients, n=2365
Sex (female) (%)	957 (40.47)
Age (mean (SD))	69.7 (12.69)
Weight (kg) (mean (SD))	84.86 (25.34)
Height (cm) (mean (SD))	168.45 (10.97)
BMI (kg/m^2) (mean (SD))	29.83 (8.31)
MBP (mm Hg) (mean (SD))	84.13 (19.15)
ICU discharge heart rate (bpm) (mean (SD))	84.26 (16.12)
ICU discharge 24-hour average heart rate (bpm) (mean (SD))	83.82 (14.49)
ICU admission heart rate (bpm) (mean (SD))	87.66 (20.46)
Temperature (°C) (mean (SD))	36.67 (0.69)
SpO_2 (%) (mean (SD))	96.69 (3.77)
Urine output (mL) (mean (SD))	1770.94 (1317.76)
Creatinine (mg/dL) (mean (SD))	1.17 (0.96)
Haemoglobin (g/L) (mean (SD))	101.4 (22.6)
Myocardial infarction (%)	949 (40.13)
Cerebrovascular disease (%)	337 (14.25)
Chronic pulmonary disease (%)	767 (32.43)
Diabetes mellitus (%)	1115 (47.15)
Renal disease (%)	1046 (44.23)
GCS (mean (SD))	13.03 (2.96)
SOFA Score (mean (SD))	5.87 (3.48)
CCI (mean (SD))	7.90 (2.57)
APS III (mean (SD))	48.96 (19.23)
SAPSII Score (mean (SD))	39.29 (11.69)
Follow-up period (day) (mean (SD))	140.26 (246.02)
Length of ICU stay (day) (mean (SD))	4.49 (5.10)
Length of hospital stay (day) (mean (SD))	13.91 (12.44)
In-hospital mortality (%)	161 (6.81)
Total mortality (%)	893 (37.76)
ICU readmission (%)	332 (14.04)

APS III, Acute Physiology Score III; BMI, body mass index; CCI, Charlson Comorbidity Score; GCS, Glasgow Coma Scale; ICU, intensive care unit; MBP, mean blood pressure; SAPSII, Simplified Acute Physiology Score II; SOFA, Sequential Organ Failure Assessment.

(dead) (p=0.027), and the 24-hour average ICU discharge heart rate was 83.18±14.00 bpm vs 84.89±15.21 bpm (p=0.006). Regarding the outcome of ICU readmission, the ICU discharge heart rate was 83.55±15.77 bpm (not ICU readmission) vs 88.64±17.49 bpm (ICU readmission) (p<0.001), and the 24-hour average ICU discharge heart rate was 83.15±14.42 bpm vs 87.94±14.23 bpm (p<0.001) (table 2). Online supplemental figure S1 shows the area under the curve for the study outcomes. According to the ROC curve, the optimal cut-off points for in-hospital mortality, total mortality and ICU readmission were 87.5 bpm, 91.5 bpm and 89.5 bpm, respectively. Thus, for this study, we selected 90 bpm as the threshold for the correlation with our outcomes of interest.

Mortality and ICU readmission

The primary and secondary outcomes were significantly higher in the group with a heart rate >90 bpm (table 3). The univariate analysis showed that elevated ICU discharge heart rate was associated with significantly increased in-hospital mortality (HR 1.034 (95% CI 1.025 to 1.042), p<0.001), total mortality (HR 1.005 (95% CI 1.001 to 1.009), p=0.012) and ICU readmission rate (HR 1.018 (95% CI 1.012 to 1.024), p<0.001). After multivariate analysis, the ICU discharge heart rate was also observed to be a strong predictor of in-hospital mortality (HR 1.032 (95% CI 1.022 to 1.041), p<0.001), total mortality (HR 1.008 (95% CI 1.004 to 1.013), p<0.001) and ICU readmission (HR 1.018 (95% CI 1.010 to 1.025), p<0.001). An ICU discharge heart rate greater than 90 bpm was significantly related to in-hospital mortality (HR 2.639 (95% CI 1.898 to 3.669), p<0.001), total mortality (HR 1.342 (95% CI 1.163 to 1.550), p<0.001) and ICU readmission (HR 1.781 (95% CI 1.413 to 2.243), p<0.001) (online supplemental table S1). The Kaplan-Meier analysis also showed that a heart rate >90 bpm was significantly related to in-hospital mortality (p<0.001), total mortality (p<0.001) and ICU readmission (p<0.001) (online supplemental figure S1).

DISCUSSION

In this clinical investigation, we were able to demonstrate that heart rate at ICU discharge was a predictor of mortality in HF patients in the MIMIC IV group. Consistent with prior research on the general population or specific patient groups, we found that a higher heart rate before ICU discharge was associated with increased in-hospital mortality among ICU patients. This association was statistically significant with an adjusted HR of 1.032 for each 1 bpm increase in heart rate in the ICU. A study has shown that heart rate on admission can predict in-hospital mortality in patients with ischaemic stroke, with a HR of 4.42 for a 10 bpm increase in heart rate.[16] Furthermore, high heart rate 24–36 hours after admission has also been associated with in-hospital mortality in patients with HF.[17]

A study found that keeping the heart rate below 100 bpm within the first day of admission could decrease mortality in ICU patients.[18] Another study showed that heart rate measured 24 hours before ICU discharge was independently linked to in-hospital and posthospital mortality after ICU discharge.[19] One study using the MIMIC-III Database showed a significant association of prolonged elevated heart rate with decreased survival in a large and heterogeneous cohort of ICU patients.[20] A separate study using the MIMIC-IV Database demonstrated that the group of patients with rheumatic heart disease who survived had a lower heart rate.[21] The HF mortality prediction models have served to advance

Table 2 Baseline characteristics between the total population and primary/secondary outcomes

	In-hospital mortality			Total mortality			ICU readmission		
Variable	Survival	Dead	P value	Survival	Dead	P value	No	Yes	P value
Patient (%)	2204 (93.20)	161 (6.81)		1472 (62.24)	893 (37.76)		2033 (86.96)	332 (14.04)	
Sex (F) (%)	887 (40.25)	70 (43.48)	0.454	575 (39.06)	382 (42.78)	0.077	822 (40.43)	135 (40.66)	0.952
Age (mean (SD))	69.31 (12.68)	75.10 (11.61)	<0.001	67.41 (12.58)	73.49 (11.93)	<0.001	69.76 (12.70)	69.38 (12.64)	0.619
Weight (kg) (mean (SD))	85.37 (25.46)	77.88 (22.58)	<0.001	88.02 (26.08)	79.64 (23.15)	<0.001	85.04 (25.32)	83.73 (25.46)	0.382
Height (cm) (mean (SD))	168.52 (11.00)	167.52 (10.56)	0.264	169.20 (10.90)	167.20 (10.98)	<0.001	168.54 (10.95)	167.90 (11.09)	0.33
BMI (kg/m^2) (mean (SD))	29.98 (8.35)	27.69 (7.40)	0.001	30.66 (8.40)	28.46 (7.98)	<0.001	29.86 (8.30)	29.63 (8.42)	0.64
MBP (mmHg) (mean (SD))	84.11 (19.24)	84.39 (17.92)	0.857	84.43 (18.76)	83.64 (19.78)	0.331	84.05 (19.12)	84.61 (19.39)	0.622
ICU discharge heart rate (bpm) (mean (SD))	83.56 (15.81)	93.84 (17.28)	<0.001	83.67 (15.36)	85.23 (17.25)	0.027	83.55 (15.77)	88.64 (17.49)	<0.001
ICU discharge 24-hour average heart rate (bpm) (mean (SD))	83.20 (14.29)	92.41 (14.55)	<0.001	83.18 (14.00)	84.89 (15.21)	0.006	83.15 (14.42)	87.94 (14.23)	<0.001
ICU admission heart rate (bpm) (mean (SD))	87.13 (20.27)	94.90 (21.66)	<0.001	86.86 (20.16)	88.98 (20.88)	0.015	87.09 (20.21)	91.16 (21.63)	0.001
Temperature (°C) (mean (SD))	36.67 (0.69)	36.68 (0.71)	0.814	36.65 (0.71)	36.70 (0.65)	0.045	36.66 (0.68)	36.74 (0.72)	0.037
SpO_2 (%) (mean (SD))	96.76 (3.67)	95.70 (4.92)	0.008	96.99 (3.50)	96.20 (4.14)	<0.001	96.71 (3.74)	96.55 (4.00)	0.459
Urine output (mL) (mean (SD))	1802.33 (1333.75)	1341.22 (981.83)	<0.001	1862.26 (1290.47)	1620.42 (1348.83)	<0.001	1792.70 (1325.29)	1637.70 (1264.41)	0.047
Creatinine (mg/dL) (mean (SD))	1.18 (0.98)	1.08 (0.67)	0.07	1.12 (0.99)	1.27 (0.91)	<0.001	1.19 (1.00)	1.06 (0.72)	0.004
Haemoglobin (g/L) (mean (SD))	101.8 (22.7)	96.0 (20.8)	0.002	103.2 (23.3)	98.5 (21.1)	<0.001	101.5 (22.8)	100.6 (21.5)	0.494
Myocardial infarction (%)	887 (40.25)	62 (38.51)	0.678	588 (39.95)	361 (40.43)	0.829	806 (39.65)	143 (43.07)	0.251
Cerebrovascular disease (%)	298 (13.52)	39 (24.22)	<0.001	194 (13.18)	143 (16.01)	0.06	281 (13.82)	56 (16.87)	0.15
Chronic pulmonary disease (%)	714 (32.40)	53 (32.92)	0.931	435 (29.55)	332 (37.18)	<0.001	650 (31.97)	117 (35.24)	0.255
Diabetes mellitus (%)	1048 (47.55)	67 (41.61)	0.164	670 (45.52)	445 (49.83)	0.046	960 (47.22)	155 (46.69)	0.859
Renal disease (%)	965 (43.79)	81 (50.31)	0.118	564 (38.32)	482 (53.98)	<0.001	892 (43.88)	154 (46.39)	0.404
GCS (mean (SD))	13.15 (2.85)	11.32 (3.71)	<0.001	13.27 (2.88)	12.64 (3.04)	<0.001	13.08 (2.93)	12.73 (3.11)	0.051
SOFA Score (mean (SD))	5.79 (3.47)	6.84 (3.48)	<0.001	5.62 (3.43)	6.28 (3.52)	<0.001	5.82 (3.44)	6.14 (3.70)	0.128
CCI (mean (SD))	7.81 (2.55)	9.25 (2.45)	<0.001	7.27 (2.43)	8.95 (2.45)	<0.001	7.83 (2.53)	8.38 (2.77)	<0.001
APS III (mean (SD))	48.10 (18.86)	60.75 (20.42)	<0.001	45.35 (18.24)	54.92 (19.35)	<0.001	48.33 (18.84)	52.86 (21.06)	<0.001
SAPSII Score (mean (SD))	38.84 (11.65)	45.43 (10.35)	<0.001	37.13 (11.51)	42.86 (11.09)	<0.001	39.09 (11.56)	40.55 (12.35)	0.034

APS III, Acute Physiology Score III; BMI, body mass index; CCI, Charlson Comorbidity Score; GCS, Glasgow Coma Scale; ICU, intensive care unit; MBP, mean blood pressure; SAPSII, Simplified Acute Physiology Score II; SOFA, Sequential Organ Failure Assessment.

Table 3 Outcome analysis by heart rate ≤90 bpm vs heart rate >90 bpm

	In-hospital mortality			
Heart rate	**Survival**	**Dead**	**Total**	**P value**
≤90 bpm	1519 (95.84)	66 (4.16)	1585	<0.001
>90 bpm	685 (87.82)	95 (12.18)	780	
Total	2204 (93.19)	161 (6.81)		
	Total mortality			
Heart rate	**Survival**	**Dead**	**Total**	**P value**
≤90 bpm	1021 (64.42)	564 (35.58)	1585	0.002
>90 bpm	451 (57.82)	329 (42.18)	780	
Total	1472 (62.24)	893 (37.76)		
	ICU readmission			
Heart rate	**No**	**Yes**	**Total**	**P value**
≤90 bpm	1404 (88.58)	181 (11.42)	1585	<0.001
>90 bpm	629 (80.64)	151 (19.36)	780	
Total	2033 (85.96)	332 (14.04)		

bpm, beats per minute; ICU, intensive care unit.

different perspectives on whether heart rate is a predictor or not. Some models suggest a strong impact on prognosis, such as the OPTIMIZE-HF study and another study that uses a GWTG-HF risk score[6 7 22] and both used heart rate at admission as a predictor. To our knowledge, there has been no report linking ICU discharge heart rate and mortality among HF patients in the ICU. Our study is the first to explore this important clinical issue. In our study, a higher last heart rate before ICU discharge was significantly associated with in-hospital/total mortality and ICU readmission. Heart rate greater than and equal to 90 bpm was strongly associated with increased in-hospital/total mortality and ICU readmission rates.

It is well-established that there is a link between heart rate and mortality. Multiple theories have been proposed to explain the association, including low physical fitness, elevated blood pressure, reduced variability in heart rate and decreased baroreceptor sensitivity in individuals with high heart rate.[23 24] However, the underlying causes of this correlation have yet to be fully understood.[25] The significance of heart rate as a prognostic indicator in acute decompensated heart failure (ADHF) remains a topic of debate. Unlike its predictive role in chronic systolic HF, the role of heart rate in ADHF is much less clear. This is partly due to variations in the timing of heart rate measurement during an acute episode and differences in the outcome measures used in various studies, such as in-hospital mortality and readmission.[26] When patients with ADHF presented at the emergency department with a higher heart rate, a higher risk of death within 7 days was linked.[27] Patients with ADHF who had a higher heart rate on arriving at the hospital were more likely to have a higher risk of death while in the hospital, with the lowest risk observed at heart rates between 70 and 75 bpm.[28]

The SHIFT trial has proved that heart rate plays a role in the progression of HF,[10] according to the speculation about a fundamental connection between a higher heart rate and the development[29] or worsening of HF,[8] with theories ranging from the impact on myocardial energy[30] to the potential benefits of reducing arterial afterload by reducing heart rate.[31]

Our findings are consistent with a large retrospective cohort study that examined HF patients who had been treated for ADHF. This study found that a higher heart rate at discharge after treatment was linked to a higher risk of death and rehospitalisation, with an even greater risk within the first 30 days following discharge.[32] Using heart rate at discharge as a predictor of risk has several benefits, including being routinely available, being easy and reliable to determine, and reflective of the patient's most stable condition, which may be more relevant for future prognosis.

Despite the large sample size and detailed data, this study has several limitations that are common to all retrospective cohort studies. These include missing data, the potential for bias in the data collection and analysis and the inability to account for all possible confounding factors. Given that the data we used originated from an observational database, and furthermore, we lacked detailed information on echocardiography and whether cardiac implantable electronic devices were installed. Due to significant variability in the timing and dosage of pharmacological treatment for HF within existing databases, analysing therapeutic efficacy and establishing causal relationships have been challenging. Therefore, this study focuses on physiological parameters and biochemical markers collected within the first 24 hours of ICU admission as primary variables for analysis. This approach aims to minimise bias arising from inconsistent treatment protocols or clinical judgement, ensuring greater reliability and comparability of the results. The results reported in our study should be regarded only as reference points and must be further verified through additional research.

CONCLUSIONS

Given the association between elevated heart rate at ICU discharge in patients with HF and increasing in-hospital mortality, total mortality and ICU readmission, it is evident that a heart rate exceeding 90 bpm correlates with an increase in these outcomes. It is important to conduct further research to determine if reducing heart rate could be an effective treatment strategy for HF patients discharged from the ICU.

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