Prognostic value of natriuretic peptide levels and in-hospital heart Failure events in patients with acute myocardial infarction

（ナトリウム利尿ペプチドと院内心不全イベントによる急性心筋梗塞患者の予後予測の検討）

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Running title: Natriuretic peptide and in-hospital HF in AMI

Keywords: myocardial infarction; percutaneous coronary intervention; natriuretic peptide; heart failure.

Abstract

Background: In patients with acute myocardial infarction (MI), an elevated level of natriuretic peptide (NP) is reportedly associated with worse clinical outcomes. I evaluated the prognostic value of NP levels and in-hospital heart failure events after MI.

Method and Results: The present bi-center registry included a total of 600 patients with acute MI undergoing percutaneous coronary intervention. HF was evaluated at 3 different timepoints after acute MI: 1) high NP on admission; 2) in-hospital HF events; and 3) high NP at short-term follow-up. When HF was present at each timepoint, one point was assigned to a risk scoring system, namely the "HF time-points", ranging from 0 to 3. The primary endpoint was a composite of all-cause death and HF rehospitalization after discharge. In patients who survived to discharge, 69 of 600 (11.5%) had the primary outcome during the mean follow-up period of 488 days. HF on admission, during hospitalization, and at short-term follow up were all significantly associated with subsequent clinical outcomes. The higher HF time-points were related to an increased risk of the primary endpoints. Multivariable analysis indicated the HF time-points of 2 and 3 were independently associated with the outcome events in a stepwise manner.

Conclusions: Among patients with acute MI, HF evaluation at different timepoints was useful to stratify risks of mortality and HF rehospitalization after discharge.

Introduction

Ischemic heart disease such as acute myocardial infarction (MI) is a major underlying pathogenic factor in heart failure (HF), accounting for approximately 50% in the current era,[1,2] and HF event is a strong predictor of worse outcomes among patients with acute MI.[3,4] B-type natriuretic peptide (BNP) and N-terminal pro-BNP (NT-proBNP) are natriuretic peptide (NP) secreted by cardiac ventricles in response to end-diastolic pressure and volume,[5] and are widely used as diagnostic biomarkers for HF in clinical practice.[6] An elevated NP level is associated with an increased risk of death and HF in patients with acute MI,[5,7] and thus NP measurement is recommended to gain prognostic information in patients with acute MI in the recent guidelines.[8] However, a trajectory of BNP and NT-proBNP levels varies widely among patients, and appropriate timing for evaluating NP after acute MI remains unclear.[9] For instance, early studies have demonstrated that a level of BNP at initial presentation of patients with ST-segment elevation MI (STEMI) predicted mortality,[10,11] while some reports indicated that NP levels during short-term follow-up after acute MI were more predictive than that at baseline.[12,13] In addition, acute HF often develops during hospitalization for acute MI,[14] but its prognostic value in combination with NP is uncertain.[3,15] Thus, in the present study, I aimed to evaluate the impact of elevated NP on admission, in-hospital HF, and a higher level of NP at short-term follow-up, and their combination on clinical outcomes after discharge in patients with acute MI.

Methods

Study population

This was a retrospective, observational, bi-center study.[16-21] From January 2012 to March 2020, a total of 1102 acute MI patients underwent primary percutaneous coronary intervention (PCI) at 2 tertiary referral centers, Chiba University Hospital and affiliated Eastern Chiba Medical Center. Acute MI including STEMI and non ST-segment elevation MI was defined according to the fourth universal definition of MI.[22] Primary PCI was performed per local standard practice with predominant use of radial access, intracoronary imaging, and new-generation drug-eluting stents.[23-27] Major exclusion criteria included in-hospital onset acute MI, late presentation >48 hours, in-hospital death, missing data on NP levels on admission or at short-term follow-up, and no follow-up information after hospital discharge (Figure 1). Thus, a total of 600 patients were included into the present study. All the participants provided written informed consent for the PCI procedure, and informed consent for this study was obtained in the form of opt-out. The present study was done in accordance with the Declaration of Helsinki and was approved by the ethical committee of Chiba University Hospital and Eastern Chiba Medical Center.

Heart failure assessment

In my institutions, patients with acute MI undergoing PCI were usually followed-up at outpatient clinic at 1 month after discharge and routinely underwent NP measurement during hospitalization and at a follow-up visit. BNP was measured at Chiba University Hospital, while NT-proBNP was available at Eastern Chiba Medical Center. All patients included into the present analysis underwent NP measurement with either BNP or NT-proBNP on admission and at short-term follow-up. The short-term follow-up NP level was obtained immediately before discharge or at 1-month outpatient visit. When data on NP levels before discharge and at 1-month follow-up were both available, the level of NP that was measured at the timing closer to 30 days after the onset of acute MI was applied as short-term follow-up data. Patients were considered to have HF when NP levels on admission and at short-term follow-up were BNP ≥200 pg/ml or NT-proBNP ≥900 pg/ml, according to the guidelines (Figure 2).[28] In addition, HF during the hospitalization was also evaluated. In-hospital HF was defined as the use of intravenous diuretics (e.g. furosemide) or vasopressors/inotropes (e.g. norepinephrine, dobutamine, and dopamine).[16,29] The use of intravenous vasodilators such as nitrates and nicorandil did not fulfill the definition of in-hospital HF. One point was assigned to the presence of HF at each timepoint (on admission, during hospitalization, and at short-term follow-up) in order to create a risk scoring system, namely the "HF time-points", ranging from 0 to 3 (Figure 2).

Endpoint and statistical analysis

Follow-up data were ascertained from medical records at Chiba University Hospital and Eastern Chiba Medical Center. The primary outcome of the present study included all-cause death and HF rehospitalization after discharge. Among patients with the HF time-points of 1 and 2, further analysis was performed to evaluate the impact of HF at different timepoints. Additionally, in patients with in-hospital HF, the relation of treatment strategies (i.e. intravenous diuretics and vasopressors/inotropes) to clinical outcomes was also investigated.

Statistical analysis was conducted using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). All data are expressed as mean ± standard deviation, median [interquartile range], or frequency (%). Continuous variables were compared with Student's t-test or Mann-Whitney U test according to the normality of distribution. Categorical variables were assessed with Fisher's exact test. The time to the primary outcomes were estimated using the Kaplan-Meier method, and the log-rank test was applied for between-group comparisons. A Cox proportional-hazards model was used to estimate adjusted hazard ratios with 95% confidence intervals for the primary outcomes. Univariable analyses were performed to identify factors associated with the primary outcomes. Associated factors with $p < 0.01$ on univariable analyses were included into a multivariable model with age and sex (irrespective of p values on univariable analyses). A value of $p < 0.05$ was considered statistically significant.

Results

A total of 600 acute MI patients who underwent primary PCI and survived to discharge were included in the present analysis. The median length of hospital stay, duration of short-term follow-up for NP measurement, and follow-up period for primary outcomes were 9 [6, 14], 32 [18, 40], and 488 [343, 934] days, respectively. During the follow-up period, 69 (11.5%) patients experienced the primary outcomes including death or HF rehospitalization after discharge. No patients had the primary outcome events before the shot-term follow-up.

Table 1 lists baseline characteristics. Patients with the primary outcome events had older age, lower body mass index, higher prevalence of comorbidities, and impaired left ventricular ejection fraction than those without (Table 1). The rates of high NP (BNP ≥200 pg/ml or NT-proBNP ≥900 pg/ml) on admission (53.6% vs. 22.1%, $p<0.001$) and at short-term follow-up (69.6% vs. 31.1%, $p<0.001$) were significantly higher in patients with the primary outcome events than their counterpart. Similarly, in-hospital HF was more frequently observed in patients experiencing all-cause death and HF rehospitalization after discharge (53.6% vs. 20.2%, $p<0.001$) (Table 1). According to the HF time-points (Figure 2), 291 (48.5%), 153 (25.5%), 110 (18.3%), and 46 (7.7%) patients had the score of 0, 1, 2, and 3, respectively (Table 2 and 3).

Kaplan-Meier analysis demonstrated that the higher HF time-points were associated with an increased risk of all-cause death and HF rehospitalization after discharge (Figure 3). In patients with the HF time-points of 1 and 2, no significant difference in the primary outcome was found among the 3 groups with HF at different timepoints (Figure 4 and 5). With respect to in-hospital HF, patients treated with both intravenous diuretics and vasopressors/inotropes had worst clinical outcomes, followed by those treated with either treatment strategy and no in-hospital HF (Figure 6). Multivariable analysis showed that the HF time-points of 2 and 3, as well as older age and a lower hemoglobin level, were independently associated with the primary endpoint in a stepwise manner (Table 4).

Table 1. Baseline patient characteristics

Variable	All (n=600)	Adverse event (-) (n=531)	Adverse event (+) (n=69)	p value
Age (years)	66.8±11.9	66.1±12.0	72.2±9.7	<0.001
Men	464 (77.3%)	411 (77.4%)	53 (76.8%)	0.88
Body mass index (kg/m^2)	24.4±3.6	24.6±3.6	23.1±3.7	0.002
Hypertension	412 (68.7%)	354 (66.6%)	58 (84.1%)	0.003
Diabetes	208 (34.7%)	182 (34.3%)	26 (37.7%)	0.59
Dyslipidemia	394 (65.7%)	356 (67.0%)	38 (55.1%)	0.06
Current smoker	209 (34.8%)	191 (36.0%)	18 (26.1%)	0.11
Previous MI	39 (6.5%)	29 (5.4%)	10 (14.5%)	0.009
Previous PCI	55 (9.2%)	43 (8.1%)	12 (17.4%)	0.02
Previous HF	11 (1.8%)	8 (1.5%)	3 (4.3%)	0.12
eGFR (ml/min/1.73 m^2)	65.6±23.6	67.4±22.6	51.5±26.5	<0.001
Hemoglobin (g/dl)	13.9±2.1	14.2±2.0	12.2±2.3	<0.001
High NP on admission	154 (25.7%)	117 (22.1%)	37 (53.6%)	<0.001
High NP at follow-up	213 (35.5%)	165 (31.1%)	48 (69.6%)	<0.001
Peak CK (U/l)	1569 [524, 3518]	1564 [515, 3380]	1890 [747, 4908]	0.16
LVEF (%)	47.7±12.2	48.4±12.0	42.5±12.5	<0.001
Cardiogenic shock	67 (11.2%)	52 (9.8%)	15 (21.7%)	0.007
Triple vessel disease	127 (21.2%)	107 (20.2%)	20 (29.0%)	0.12
Type of MI				0.33
STEMI	421 (70.2%)	376 (70.8%)	45 (65.2%)	
NSTEMI	179 (29.8%)	155 (29.2%)	24 (34.8%)	
Medication at discharge				
Aspirin	564 (94.0%)	501 (94.4%)	63 (91.3%)	0.29
P2Y12 inhibitor	579 (96.5%)	515 (97.0%)	64 (92.8%)	0.07
Statin	562 (93.7%)	502 (94.5%)	60 (87.0%)	0.03
ACE-i or ARB	600 (100%)	531 (100%)	69 (100%)	1.00
β-blocker	471 (78.5%)	416 (78.3%)	55 (79.7%)	0.88
MRA	111 (18.5%)	89 (16.8%)	22 (31.9%)	0.005
Diuretic	134 (22.3%)	96 (18.1%)	38 (55.1%)	<0.001
SGLT2 inhibitor	20 (3.3%)	18 (3.4%)	2 (2.9%)	1.00

In-hospital HF	144 (24.0%)	107 (20.2%)	37 (53.6%)	<0.001

Adverse event indicates the primary outcome, a composite of all-cause death and HF rehospitalization after discharge. In-hospital HF was defined as the use of intravenous vasopressors, inotropes, and diuretics during the index hospitalization for acute MI.

ACE-I, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CK, creatine kinase; eGFR, estimated glomerular filtration rate; HF, heart failure; LVEF, left ventricular ejection fraction; MI, myocardial infarction; MRA, mineralocorticoid receptor antagonist; NP, natriuretic peptide; NSTEMI, non ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention; SGLT2, sodium-glucose cotransporter 2; STEMI, ST-segment elevation myocardial infarction.

Table 2. Baseline patient characteristics among 4 groups according to the HF time-points

Variable	HF time-points				p value
	0 (n=291)	1 (n=153)	2 (n=110)	3 (n=46)	
Age (years)	63.2±11.6	68.3±11.6	71.1±10.6	73.8±11.3	<0.001
Men	239 (82.1%)	111 (72.5%)	80 (72.7%)	34 (73.9%)	0.051
Body mass index (kg/m^2)	24.9±3.8	24.2±3.5	23.8±3.5	23.3±3.0	0.006
Hypertension	184 (63.2%)	114 (74.5%)	78 (70.1%)	36 (78.3%)	0.04
Diabetes	98 (33.7%)	48 (31.4%)	34 (30.9%)	19 (41.3%)	0.43
Dyslipidemia	200 (68.7%)	107 (69.9%)	63 (57.3%)	24 (52.2%)	0.02
Current smoker	123 (42.2%)	45 (29.4%)	32 (29.1%)	9 (19.6%)	0.002
Previous MI	22 (7.6%)	5 (3.3%)	8 (7.3%)	4 (8.7%)	0.25
Previous PCI	27 (9.3%)	10 (6.5%)	12 (10.9%)	6 (13.0%)	0.43
Previous HF	1 (0.3%)	2 (1.3%)	6 (5.5%)	2 (4.3%)	0.002
eGFR (ml/min/1.73 m^2)	73.4±20.8	63.7±22.5	54.4±25.4	48.8±19.2	<0.001
Hemoglobin (g/dl)	14.4±1.9	14.1±2.1	13.2±2.1	12.1±2.4	<0.001
High NP on admission	0 (0%)	39 (25.5%)	70 (63.6%)	46 (100%)	<0.001
High NP at follow-up	0 (0%)	75 (49.0%)	92 (83.6%)	46 (100%)	<0.001
Peak CK (U/l)	1045 [284, 2156]	2557 [1187, 4430]	2497 [778, 5607]	2429 [2021, 5038]	<0.001
LVEF (%)	53.3±10.0	44.8±11.2	41.5±11.3	36.5±11.9	<0.001
Cardiogenic shock	8 (2.7%)	23 (15.0%)	26 (23.6%)	10 (21.7%)	<0.001
Triple vessel disease	52 (17.9%)	26 (17.0%)	30 (27.3%)	19 (41.3%)	0.001
Type of MI					<0.001
STEMI	173 (59.5%)	126 (82.4%)	86 (78.2%)	36 (78.3%)	
NSTEMI	118 (40.5%)	27 (17.6%)	24 (21.8%)	10 (21.7%)	
Medication at discharge					

Aspirin	285 (97.9%)	142 (92.8%)	98 (89.1%)	39 (84.8%)	<0.001
P2Y12 inhibitor	286 (98.3%)	150 (98.0%)	99 (90.0%)	44 (95.7%)	0.001
Statin	277 (95.2%)	146 (95.4%)	99 (90.0%)	40 (87%)	0.050
ACE-i or ARB	291 (100%)	153 (100%)	110 (100%)	46 (100%)	1.00
β-blocker	211 (72.5%)	127 (83.0%)	96 (87.3%)	37 (80.4%)	0.004
MRA	19 (6.5%)	27 (17.6%)	41 (37.3%)	24 (52.2%)	0.005
Diuretic	12 (4.1%)	34 (22.2%)	55 (50.0%)	33 (71.7%)	<0.001
SGLT2 inhibitor	13 (4.5%)	1 (0.7%)	4 (3.6%)	2 (4.3%)	0.12
In-hospital HF	0 (0%)	40 (26.1%)	58 (52.7%)	46 (100%)	<0.001

Adverse event indicates the primary outcome, a composite of all-cause death and HF rehospitalization after discharge. In-hospital HF was defined as the use of intravenous vasopressors, inotropes, and diuretics during the index hospitalization for acute MI.

ACE-I, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CK, creatine kinase; eGFR, estimated glomerular filtration rate; HF, heart failure; LVEF, left ventricular ejection fraction; MI, myocardial infarction; MRA, mineralocorticoid receptor antagonist; NP, natriuretic peptide; NSTEMI, non ST-segment elevation myocardial infarction; PCI, percutaneous coronary intervention; SGLT2, sodium-glucose cotransporter 2; STEMI, ST-segment elevation myocardial infarction.

Table 3. Clinical outcomes

Variable	All (n=600)	HF time-points				p value
		0 (n=291)	1 (n=153)	2 (n=110)	3 (n=46)	
Primary endpoint	69 (11.5%)	15 (5.2%)	7 (4.6%)	26 (23.6%)	21 (45.7%)	<0.001
All-cause death	40 (6.7%)	13 (4.5%)	3 (2.0%)	13 (11.8%)	11 (23.9%)	<0.001
HF rehospitalization	35 (5.8%)	2 (0.7%)	4 (2.6%)	15 (13.9%)	14 (32.6%)	<0.001

HF, heart failure.

Table 4. Factors associated with primary endpoint

Variable	Univariable		Multivariable	
	HR (95% CI)	p value	HR (95% CI)	p value
Age (years)	1.06 (1.04-1.09)	<0.001	1.03 (1.00-1.06)	0.048
Men	0.91 (0.52-1.59)	0.73	1.59 (0.88-2.86)	0.13
Body mass index (kg/m^2)	0.91 (0.85-0.98)	0.008	0.95 (0.88-1.03)	0.25
Hypertension	2.51 (1.32-4.80)	0.005	1.73 (0.86-3.50)	0.13
eGFR (ml/min/1.73 m^2)	0.97 (0.96-0.98)	<0.001	0.99 (0.98-1.00)	0.13

Hemoglobin (g/dl)	0.72 (0.65-0.79)	<0.001	0.85 (0.75-0.97)	0.01
LVEF (%)	0.96 (0.95-0.98)	<0.001	0.99 (0.97-1.01)	0.43
Cardiogenic shock	2.20 (1.24-3.90)	0.007	1.34 (0.68-2.61)	0.39
HF time-points = 0	Reference		Reference	
HF time-points = 1	0.90 (0.37-2.2)	0.82	0.64 (0.25-1.64)	0.35
HF time-points = 2	4.96 (2.62-9.38)	<0.001	2.61 (1.24-5.47)	0.01
HF time-points = 3	11.71 (6.00-22.85)	<0.001	4.17 (1.72-10.11)	0.002

CI, confidence interval; eGFR, estimated glomerular filtration rate; HF, heart failure; HR, hazard ratio; LVEF, left ventricular ejection fraction.

Discussion

In the present bi-center registry, HF events were frequently observed on admission, during hospitalization, and at short-term follow-up (median 32 days after the index MI) in 25.7%, 24.0%, and 35.5% in patients with acute MI who underwent PCI and survived to discharge, all of which were associated with an increased risk of subsequent clinical events including all-cause death and HF rehospitalization. When the presence or absence of HF events at the 3 timepoints was compounded, patients with the “HF time-points” of 2 and 3 had a higher risk of death and HF rehospitalization after discharge, while those with the HF time-points of 1 did not, irrespective of the timing of HF (i.e. on admission, during hospitalization, and at short-term follow-up).

Natriuretic peptide levels in acute myocardial infarction

A large future increase in the prevalence of cardiovascular diseases such as MI and HF is currently projected across the world, including Japan and the United States.[30,31] The prevalence is estimated to rise for MI (16.9% increase compared with 2025; 4.9% of the population or 16.0 million persons) and for HF (33.4% increase compared with 2025; 4.0% of the population or 12.9 million persons) by 2060 in the United States.[31] Because acute MI is a major etiology of HF,[1,2] the identification of acute MI patients at a high risk of developing future HF is clinically relevant in the current “heart failure pandemic” era.[30,32] In this context, the measurement of BNP or NT-proBNP plasma concentrations is recommended to gain prognostic information in patients with non ST-segment elevation MI in the recent guidelines (Class IIa),[8] but appropriate timing for evaluating NP levels in acute MI patients remains unclear. A single-center, observational study (n=1034) showed that NT-proBNP ≥150 and 600 pg/ml at initial presentation of patients with STEMI was associated with higher mortality during the median follow-up of 901 days in a stepwise manner.[11] Further, previous studies have indicated the prognostic impact of NP levels at short-term follow-up after acute MI, such as those at median of 3 days,[33] median of 6 days,[13] 3-4 weeks,[7] and median of 56 days.[12] In a previous study, the plasma BNP level measured 3 to 4 weeks after the onset of acute MI was an independent predictor of cardiac death with the best-cut off value of 180 pg/ml, which is in line with my results (i.e. BNP ≥200 pg/ml or NT-proBNP ≥900 pg/ml).[7] Among patients with the HF time-points of 2, the lack of HF at short-term follow-up was apparently associated with better outcomes, although not significantly different. In addition to individual NP assessment on admission and at short-term follow-up, a combination NP evaluation has been investigated to stratify future cardiovascular risks after acute MI. A single-center study by Lee et al. (n=442) reported that when patients were divided into 4 groups according to the initial and follow-up median BNP levels, patient with high BNP levels both at initial and follow-up measurements (i.e. high-high group) had worst clinical outcomes after acute MI, followed by the low-high group and the low-low group, suggesting that patients who had an elevated BNP level during the initial admission that subsequently reduced had good prognosis.[12] Similar results were shown in the multi-center TRIUMPH registry (n=803),[34] although the “low-high” group was excluded in the study because of the small sample size. Thus, whether elevated levels of NP on admission and at short-term follow-up were independently prognostic after acute MI remained uncertain. The present study demonstrated that elevated BNP or NT-proBNP levels on admission and at median of 32 days were both associated with an increased risk of clinical events, but patients having a high NP level at either timepoint did not result in the increased risk if no in-hospital HF events occurred (Figure 4). Therefore, serial assessment of NP may be useful to determine future cardiovascular risks after acute MI, especially when persistently elevated. Given the fact that hazard ratios were increased in a stepwise manner in the multivariable model (Table 4), the presence of HF at 2 and 3 timepoints was predictive for worse clinical outcomes after acute MI.

In-hospital heart failure after acute myocardial infarction

Although the incidence has declined over time owing to advances in early reperfusion therapy and medical treatment, in-hospital HF developing after acute MI is still a major complication affecting up to 30% of patients,[14,35] which is in line with my results (i.e. 24.0%). The presence of HF during hospitalization for acute MI was intuitively associated with short- and long-term morality.[14,35] Additionally, it was reported that HF developing >3 days after acute MI was more predictive for cardiovascular events as compared with early-onset HF (≤3 days).[3] Nevertheless, the prognostic value of in-hospital HF in combination with initial and follow-up NP levels are poorly investigated. In the present study, in-hospital HF itself was not predictive for subsequent mortality and HF readmission risks unless either or both elevated levels of NP on admission and at short-term follow-up were accompanied (i.e. HF time-points of 1). Thus, we believe that the combination evaluation of HF after acute MI with the novel scoring system, HF time-points, may be useful in daily practice. Interestingly and notably, intensity of HF treatment, represented by the use of intravenous diuretics and/or vasopressors/inotropes, was significantly associated with clinical outcomes after acute MI (Figure 6). Therefore, further risk stratification would be possible with more factors associated with clinical outcomes, especially using artificial intelligence technology.[36]

Study limitations

The present study has some limitations. This was retrospective study with a moderate sample size, and the number of excluded patients was relatively large. Because of the retrospective and exploratory nature of the present study, no sample size calculation was performed. Future studies are needed to externally confirm the diagnostic ability of HF time-points. Despite the recent advances in HF treatment including sodium-glucose cotransporter 2 inhibitor, the number of patients receiving such a treatment was limited. In the present study, we employed both BNP and NT-proBNP as NP measurement because of institutional availability. Thus, NP levels were used as being dichotomous (i.e. BNP ≥200 pg/ml or NT-proBNP ≥900 pg/ml). NP was routinely measured on admission and at short-term follow-up, while the NP measurement during hospitalization for acute MI varied widely among individual cases in my institutions, preventing HF evaluation by NP levels during hospitalization. The timing of short-term follow-up of NP measurement was not uniformed in the present study, although none of participants had the primary outcome events before the NP measurement at short-term follow-up. Further investigations are warranted to improve clinical outcomes in patients with acute MI complicated by HF.[37-39]

Conclusion

Among patients with acute MI who underwent PCI and survived to discharge, the evaluation of HF on admission, during hospitalization, and at short-term follow-up, was useful to stratify risks of mortality and HF rehospitalization after discharge when HF was presented at 2 or 3 timepoints.

Disclosure

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Data Availability

The deidentified participant data will not be shared.

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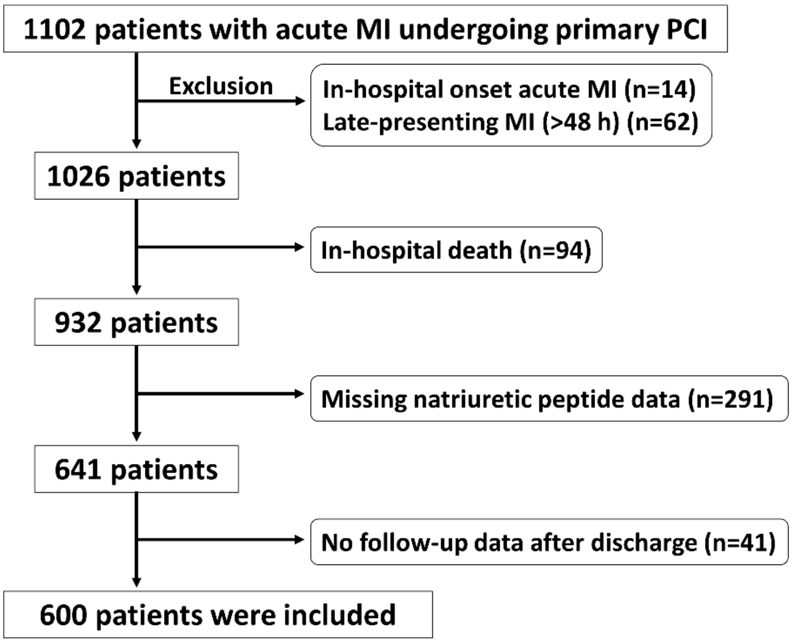
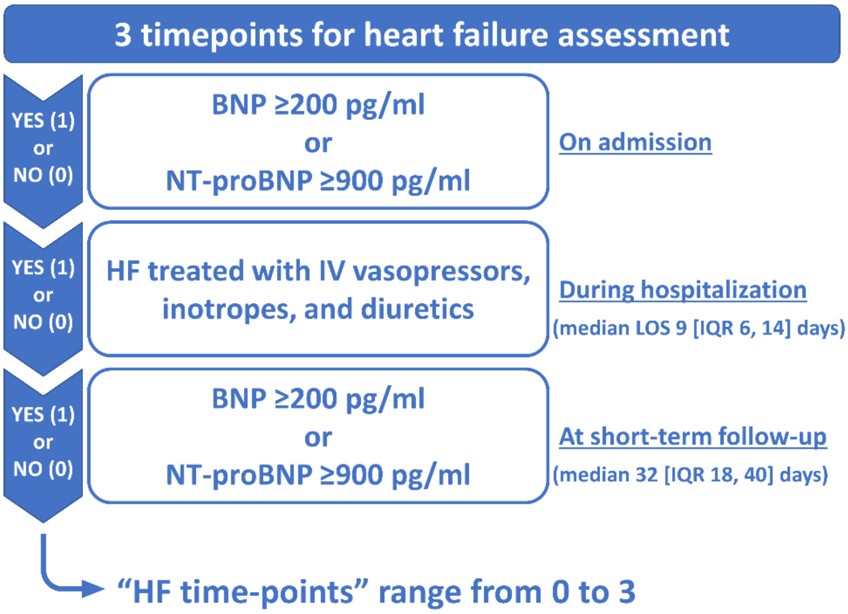
Figure legends

Figure 1. Study flow



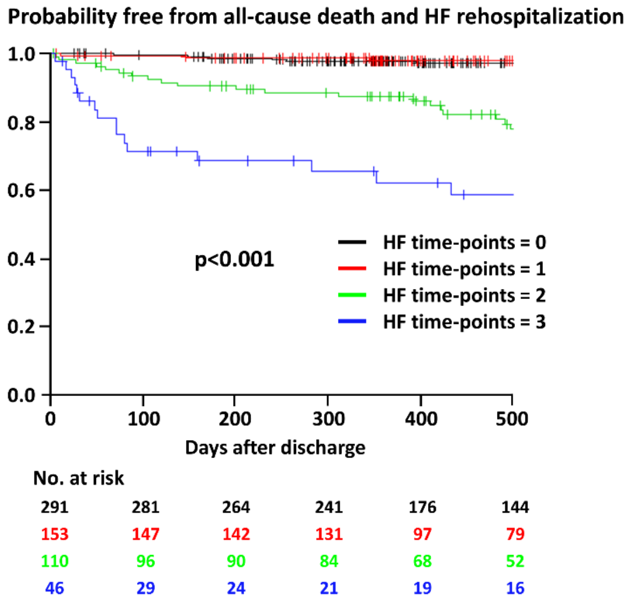
MI, myocardial infarction; PCI, percutaneous coronary intervention.

Figure 2. Timepoints for HF assessment



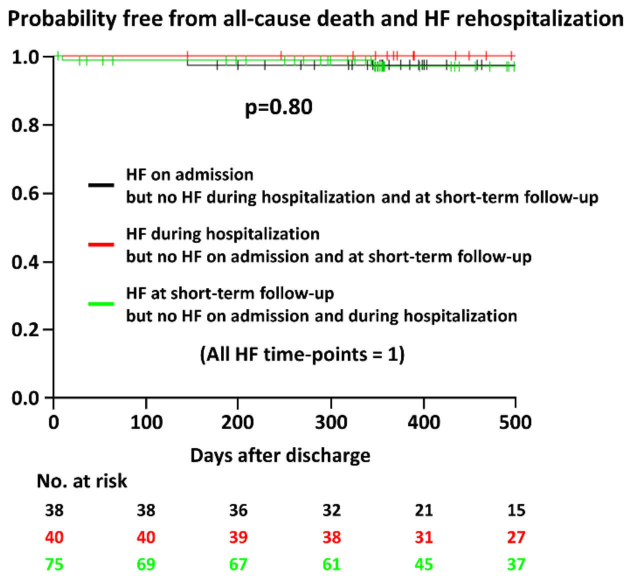
BNP, B-type natriuretic peptide; HF, heart failure; IQR, interquartile range; IV, intravenous; LOS, length of hospital stay; NT-proBNP, N-terminal pro-BNP.

Figure 3. Probability free from all-cause death and HF rehospitalization after discharge according to the HF time-points



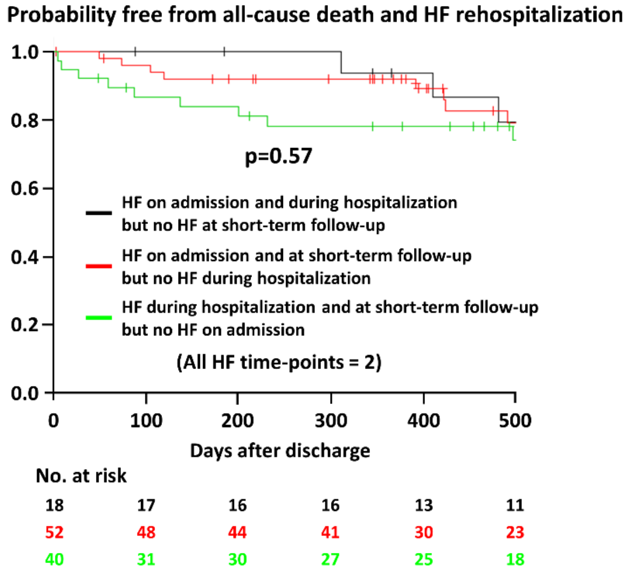
HF, heart failure.

Figure 4. Probability free from all-cause death and HF rehospitalization after discharge among patients with the HF time-points of 1



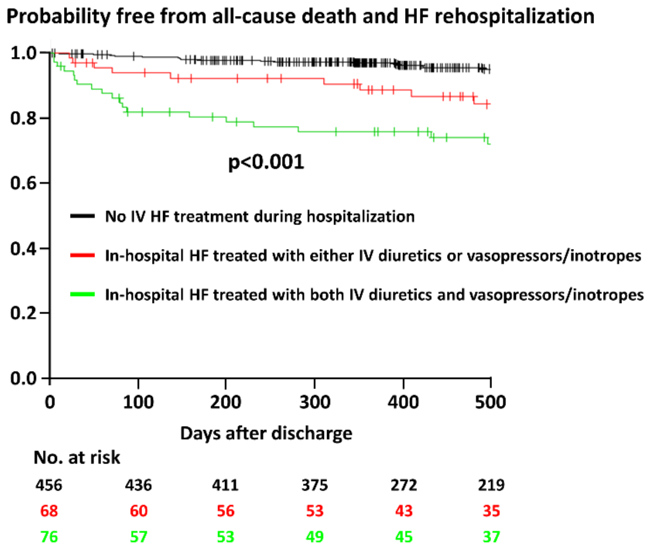
HF, heart failure.

Figure 5. Probability free from all-cause death and HF rehospitalization after discharge among patients with the HF time-points of 2



HF, heart failure.

Figure 6. Probability free from all-cause death and HF rehospitalization after discharge according to in-hospital HF and the treatment strategies



HF, heart failure; IV, intravenous.

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