Clinical Prediction of Acute Heart Failure Patient for Hospital Admission form ED

Sricharoen P[1], Yuksen C[1*], Phinyo P[2,3], Patumanond J[2], Piyayotai D[4], Sittichanbuncha Y[1], Likittanasombat K[5], and Cheuathonghua E[1]

[1]Department of Emergency Medicine, Ramathibodi Hospital, Mahidol University, Thailand

[2]Department of Family Medicine, Chiang Mai University, Thailand

[3]Center for Clinical Epidemiology and Clinical Statistics, Chiang Mai University, Thailand

[4]Department of Medicine, Thammasat University, Thailand

[5]Department of Internal Medicine, Ramathibodi Hospital, Thailand
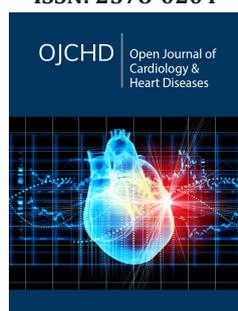
*Corresponding author: Yuksen C, Department of Emergency Medicine, Ramathibodi Hospital, Thailand

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Abstract

Introduction: Delay hospitalization in acute heart failure patients was the risk of complications, delay definite diagnosis, and treatment. This study aims to create a predictive score to predict hospitalization in acute heart failure patients.

Methods: Retrospective cohort design and collected data of acute heart failure patients in the emergency department. Predictive factors obtained from patients' characteristics, underlying diseases, medical signs, vital signs on admission, a preliminary examination in the emergency department, and factors were stimulating acute heart failure in patients. Predictive factors were chosen from multivariable logistic regression and converted into predictive scores.

Result: 151 patients stayed in the hospital for more than 24 hours, and 62 patients stayed in the hospital for less than 24 hours. Predictive factors included NYHA (New York Heart Association) functional class, temperature, and patients' breathing rate observed on admission, albumin levels, factors stimulating acute heart failure in patients caused by the acute coronary syndrome. Scores could predict more than 24 hours of hospital stay. AuROC was 85.27% (95% CI; 79.82, 90.73). Predictive scores were divided into 3 groups as the group with high scores (7.5-13.5), moderate scores (3.5-7), and low scores (0-3) being at risk of hospitalization longer than 1- day by 100%, 72.7% (95% CI;65.7, 79.8) and 16.7% (95% CI; 1.8, 31.6) respectively.

Conclusion: The scores can be used to predict hospitalization or ED length of stay for more than 24 hours for acutely decompensated heart failure patients in the emergency department.

Introduction

Acute heart failure is an important public health problem of the global population. In the United States, nearly one million patients visit emergency departments every year, and 83.7% were admitted on averagely of 3.4 days [1], and the mortality rate about 4-5% [2]. In Thailand, the hospitalization rate was averagely 7.5 days, and the mortality rate was about 5.4% [3]. One of the possible reasons was patient hospitalization assigned by the emergency physician was more delayed; there was not enough bed for hospitalization, ending up in a higher mortality rate [4].

The factors affecting the hospital stay was gender [5-7], age [8], diabetes [9,10], coronary heart disease [9,11], chronic kidney failure [9,12,13], arrhythmia [14], patients with high New York Heart Association (NYHA) functional class [15,16], patients with edema, patients with low levels of hemoglobin, sodium, and albumin [10-13,15]. However, each study had a difference in determining hospital stay from 4-7 days [5-15], and patients with delayed hospital admission had a higher mortality rate [4].

Generally, the severity of decompensated heart failure ranges from patients experiencing slight tiredness, shall have the preliminary treatment in the emergency department and discharged. Patients shall admit to the hospital for further treatment in moderate symptoms and severe symptoms requiring immediate treatment and admission in an intensive care

unit [16]. In a mild and moderate acute heart failure symptom, the patients need to be treated in the emergency department, and clinical observation. The average length of stay in acute heart failure patients was 29.76 hours. Delay in hospitalization was the risk of complications, including emergency department crowding, delay definite diagnosis and treatment [4].

In the Emergency department, Ramathibodi hospital, Mahidol University, a university-affiliated super tertiary care hospital in Bangkok, Thailand. There was overcrowding in ED and not enough bed for admission of all mild and moderate heart failure. They had to treat and observe in ED; if the clinical did not improve within 24 hours, the patients would be assigned to hospitalization. There was no study to predict the heart failure patients to stay in the ED for more than 24 hours and necessary to hospitalization. This study aims to create a predictive score to predict hospitalization in acute heart failure patients.

Methods

Study design and setting

This is retrospective cohort study included the acutely decompensated heart failure patients visiting the emergency department from January 2016 to December 2017 in Ramathibodi hospital; 62,991 patients receive services at the emergency department. The ethics committee approved the research methodology, data collection, and result interpretation. MURA2017/650/ID 09-60-40 and MTU-EC-ES-0-026/61. This research does not require a process of informed consent since it was a retrospective study of medical records.

Participant

We collected the data from electronic medical records (EMR). We included the participant who older than 18 years, visiting the emergency department from January 2016 to December 2017, diagnosed with acute decompensated heart failure, code I110, I130, I500, I509, and E877. We excluded the patient's need for endotracheal intubation within the first 6 hours in ED because they seemed to have severe symptoms and were required hospitalization. We excluded the patients who transferred from other hospitals and refused treatment.

Definitions and procedures

Data were collected from retrospective medical records, and the variable was obtained within the first 6 hours of patients arriving at the ED. We include the decompensated heart failure according to Framingham criteria [17] (either 2 major criteria or 1 major 2 minor criteria), and the pro-BNP value was more significant than 300pg/mL.

We collect all of the variables that may confound the decompensated heart failure patients to stay in the ED for more than 24 hours and necessary for hospitalization. All variables included gender, age, underlying diseases (diabetes, coronary heart disease, chronic kidney failure, arrhythmia), NYHA functional class, edema, blood pressure, body temperature, heart rate, breathing rate, levels of hemoglobin, sodium, albumin, and N-terminal pro-brain natriuretic peptide (NT-proBNP), and chest x-ray results. We used the complete-case analysis for the missing data.

We used the data from the pilot study to calculate the sample size. A pilot study was conducted in 30 decompensated heart patients who arrived at the emergency department, using inclusion and exclusion criteria. We used STATA version 14, setting power of 80% and a significance level of 5% (two-sided). The ratio of sample size was 1:1 found that the minimum sample size should be 150.

Data gathering

We recorded all of the variables and the outcome of a length of stay in the ED and divided the decompensated heart failure into two groups (more than 24 hours and less than 24 hours length of stay in the ED).

Statistical analysis

We used t-test and exact probability test to compare the prediction factor. Each factor was predicted using univariable logistic regression and showed an area under the receiver operating characteristic (AuROC) curve and 95% confidence interval (95% CI). Variables with high AuROC and significant p-value (<0.05) were used as predictors and calculated using multivariable logistic regression.

The obtained scores were considered to be predictive factors of hospitalization for more than 24 hours using logistic regression. The goodness of fit statistics (GOF) was tested using the Hosmer-Lemeshow statistics. The predicted results from the scores were compared with actual outcomes and illustrated by calibration plots. The obtained scores were divided into three groups; high, medium, and low. Prediction ability was shown as a chance that patients shall stay in the hospital longer than 24 hours when patients being at a particular group (positive predictive value), 95% confidence, and a statistical significance level. The bootstrap method was used to examine the equation's inner parts to find its prediction efficiency using the existing data to run a random test within 500 times. The AuROC curve illustrated the efficiency of the internal examination.

Result

All 213 patients comprise 151 patients hospitalized more than 24 hours, and 62 patients hospitalized less than 24 hours. The findings showed that factors affecting hospitalization more than 24 hours were patients had diabetes (57% vs 38.7%, p=0.017), NYHA functional class 3-4 (64.2% vs 40.3%, p=0.002), patients had high breathing rate (26.1±5.3 vs 24.2±3.9, p = 0.011), body temperature was higher than 37.4 degree Celsius (18.5% vs 3.2%, p< 0.001), low albumin levels (2.9±0.6 vs 3.2±0.5 g/L, p=0.001), x-ray result showing pulmonary congestion (87.4 % vs 66.1%, p < 0.001) as shown in Table 1.

Table 1: Baseline clinical characteristics of study participants categorized by length of stay.

Characteristics	LOS				P-value	AuROC (95%CI)
	≥24 hours (n=151)		<24 hours (n=62)			
	Mean	**±SD**	**Mean**	**±SD**		
Demographic						
Age (year)	74.7	12.5	73	14.5	0.368	0.53 (0.44-0.62)
Female (n,%)	62	41.1	22	35.5	0.537	0.53 (0.46-0.60)
Comorbidities, (n,%)						
Diabetes	86	57	24	38.7	0.017	0.59 (0.52-0.66)
Chronic kidney disease	81	53.6	24	38.7	0.051	0.57 (0.50-0.65)
Ischemic heart disease	64	42.4	22	35.5	0.362	0.53 (0.46-0.61)
Atrial fibrillation	55	36.4	30	48.4	0.124	0.44 (0.37-0.51)
Mode of presentation, (n,%)						
NYHA Functional class						
Class 0-2	54	35.8	37	59.7	0.002	0.62 (0.55-0.69)
Class 3-4	97	64.2	25	40.3		
Peripheral edema	106	70.2	47	75.8	0.503	0.47 (0.41-0.54)
Vital signs and hemodynamics						
SBP (mmHg)	150.9	35.5	156.1	36.3	0.336	0.46 (0.37-0.54)
DBP (mmHg)	78.8	19.5	82.7	16.9	0.164	0.43 (0.34-0.51)
Heart rate (/min)	92.6	26	86.7	20.3	0.112	0.54 (0.46-0.62)
Respiratory rate (/min)	26.1	5.3	24.2	3.9	0.011	0.60 (0.52-0.68)
Arterial oxygen saturation (%)	93.1	5.5	94.5	5	0.087	0.41 (0.32-0.50)
Body temperature (Celsius)[17]						
<37.0	94	62.3	31	50	<0.001	0.67 (0.61-0.74)
37.0-37.4	29	19.21	29	46.8		
>37.4	28	18.5	2	3.2		
Laboratory and imaging						
Hemoglobin (g/dL)	10.6	2.1	11	2	0.191	0.43 (0.35-0.52)
Serum sodium (mEq/L)	136.4	6.5	137.4	4.7	0.289	0.47 (0.39-0.56)
Serum albumin (g/dL)	2.9	0.6	3.2	0.5	0.001	0.35 (0.27-0.43)
Serum proBNP (10^3pg/mL)	15.6	19.2	11.6	15.7	0.147	0.59 (0.50-0.67)
Pulmonary congestion* (n,%)	132	87.4	41	66.1	<0.001	0.61 (0.54-0.67)

The precipitating factors of acute decompensated heart failure that affecting hospitalization more than 24 hours were arrhythmia (23.8% vs 6.5%, p=0.003), acute coronary syndrome (14.6 % vs 3.2 %, p = 0.017), and drug withdrawal (4 % vs 12.90 %, p=0.029) as shown in Table 2.

Table 2: Precipitating factors of acute decompensated heart failure.

Precipitating Factors	LOS				P-value	AuROC (95%CI)
	≥24 hours (n=151)		<24 hours (n=62)			
	Mean	**±SD**	**Mean**	**±SD**		
Salt and water retention	37	24.5	22	35.5	0.129	0.45 (0.38-0.51)
Drug withdrawal	6	4	8	12.9	0.029	0.46 (0.41-0.50)
Valvular heart disease	41	27.2	13	21	0.39	0.53 (0.47-0.59)
Dilated cardiomyopathy	18	11.9	6	9.7	0.812	0.51 (0.47-0.56)
Acute coronary syndrome	22	14.6	2	3.2	0.017	0.56 (0.52-0.59)
Anemia	10	6.6	3	4.8	0.761	0.51 (0.48-0.54)
Arrhythmia	36	23.8	4	6.5	0.003	0.59 (0.54-0.63)

The best predictive factors to predict a chance of hospitalization more than 24 hours were NYHA functional class 3-4, breathing rate more than 24 per minute, body temperature, albumin level lower than 3.5 g/dL, chest x-ray result showing pulmonary congestion, stimulating factors from arrhythmia and acute coronary syndrome. The predictive factors were converted into scores using the logistic regression coefficient, as seen in Table 3. The predictive scores were combined with being the total scores of each patient. The total scores ranged from 0 to 13.5 points. The obtained total scores could predict a chance of hospitalization for more than 24 hours of patients, AuROC curve reached 85.27% (95% CI; 79.82, 90.73) (Figure 1), and the Hosmer-Lemeshow test was 0.8902.
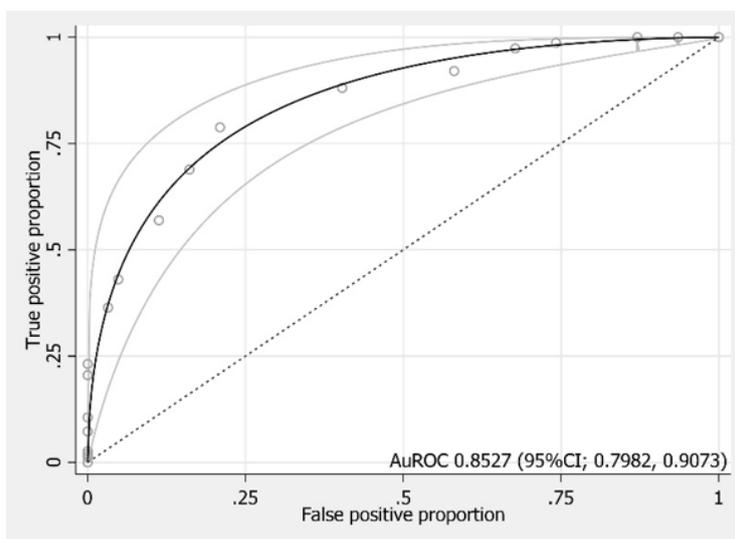

Figure 1: Parametric ROC curve.

Table 3: Multivariable prognostic prediction model of prolonged ED stay.

Predictors	OR	95% CI	P-value	ß	Score
Mode of presentation NYHA functional class					
Class 3-4	4.11	1.90-8.91	<0.001	1.4135	1.5
Vital signs and hemodynamics					
Tachypnea (RR >24/min)16	2.7	1.23-5.92	0.013	0.9946	1
Body temperature (Celsius)17					
<37.0	6.2	2.65-14.51	<0.001	1.825	2
37.0-37.4	1	Ref	Ref	Ref	0
> 37.4	22.63	4.16-123.06	<0.001	3.1191	3
Laboratory and imaging					
Serum albumin <3.5 g/dL18	4.37	1.70-11.21	0.002	1.4752	1.5
Pulmonary congestion*	2.89	1.20-6.98	0.018	1.0621	1
Precipitating factors					
Acute coronary syndrome	5.5	1.71-24.33	0.06	1.7052	1.5
Cardiac arrhythmias	6.45	1.71-24.33	0.006	1.8648	2

Table 4: Classification of risk groups.

Risk Groups	Score	LOS				PPV	95% CI	P-value
		≥24 hours (n=151)		<24 hours (n=62)				
		n	%	n	%			
Low	0-3.0	4	16.7	20	83.3	16.7	1.8-31.6	0.028
Moderate	3.5-7.0	112	72.7	42	27.3	72.7	65.7-79.8	<0.001
High	7.5-13.5	35	100	0	0	100	n/a	<0.001
Mean±SE		6.15	0.14	3.89	0.18			<0.001

If scores were more significant, a higher chance of being hospitalized for more than 24 hours would become (Figure 2 & Figure 3). Based on Figure 2 & Figure 3, patients' scores were divided into three groups. The group with scores of 0-3 points was a low chance of hospitalization. The group with scores of 3.5-7 points was a moderate chance of hospitalization, and the group with scores 7.5-13.5 points was a high chance of hospitalization. Positive predictive values were 16.7% (95% CI; 1.8, 31.6), 72.7% (95% CI; 65.7, 79.8) and 100% respectively (Table 4).
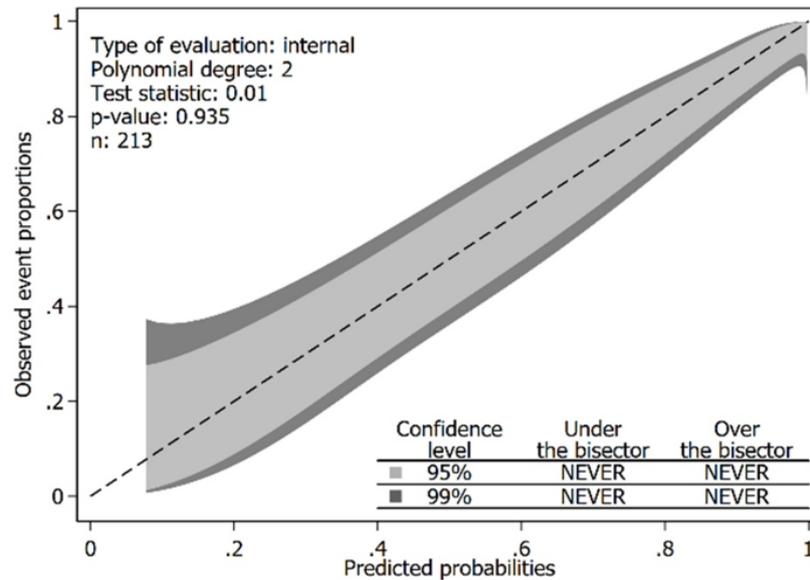

Figure 2: Internal calibration plots.
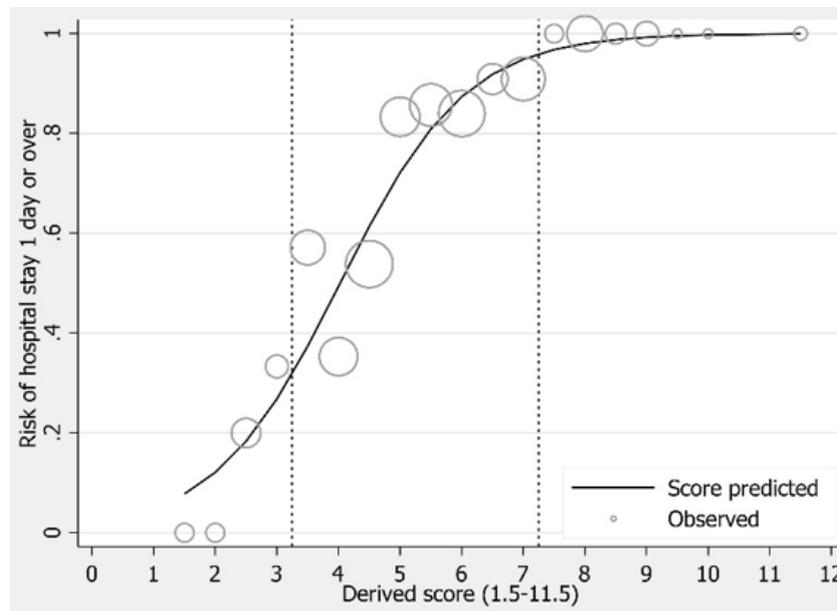
Figure 3: Internal calibration plots.

Discussion

This study aims to seek a predictive equation to predict the acutely decompensated heart failure patients visiting the emergency department, in the group without severe symptoms, who have a chance to be hospitalized or ED length of stay more than 24 hours. The predictive equation consists of 7 variables: NYHA functional class [3,4], breathing rate faster than 24 per minute, body temperature less than 37 and higher than 37.4 degree Celsius, albumin level lower than 3.5 g/dL, chest x-ray result showing pulmonary congestion, precipitating factors from arrhythmia and acute coronary syndrome. Patients with a score higher than 7 points

shall be in the group of patients having a chance to be hospitalized or ED length of stay for more than 24 hours. The emergency physician should admit the high chance of hospitalization group as soon as possible. If delay hospitalized, patients would delay treatment in the emergency department, resulting in emergency department crowding and complications in patients [18].

The study of Nam-Kyoo L et al. [19] in Korea was conducted to evaluate the prediction factor to predict the 30 days revisit. The prediction factor accordingly with our variable was NYHA functional class, systolic blood pressure. In the previous studies, variables were used to predict treatment outcomes from history (NYHA function class), vital signs, laboratory results, and drug use after patient discharge. In the NYHA functional class at level 3 and above, the patients were the worst outcome [19-21].

The patients' vital signs on admission were used to predict patients' 30 days mortality but were not used to predict hospitalization. Patients with low systolic blood pressure and breathing rate higher than 24 times per minute were increasing a chance of 30 days of mortality. Variables related to albumin levels in blood and arrhythmia were found to enable patients to stay in the hospital again, but it was not found that they were used to create an equation [22,23]. The prediction of patients' body temperature on admission, chest X-ray result showing pulmonary congestion, and factors stimulating acute heart failure to calculate predictive scores since patients with non-normal body temperature had a chance to have an infection, causing them to stay in the hospital longer than 24 hours [24,25]. The patients with pulmonary congestion shown by chest X-ray tended to be hospitalized longer as well [26]. Patients expected that coronary heart disease is the cause of acute coronary syndrome; they had a poor disease prediction and need to be hospitalized [23,27,28].

Limitations

There are some limitations to this study. First, this study was a retrospective study, and some patients having incomplete medical records were excluded. Second, a cut-off at 24 hours of hospitalization was different from other studies, depending on the ED context with hospital beds' deprivation. Meanwhile, only internal validation was conducted in this study, in which external validation should be conducted further.

Conclusion

The scores can be used to predict hospitalization or ED length of stay for more than 24 hours for acutely decompensated heart failure patients in the emergency department.

Declarations

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No

Conflict of interest statement

None of the authors have any conflicts of interest to disclose.

Source of funding

Data availability statement

The data are not available for public access because of participants privacy concern but are available from the corresponding author upon reasonable request.

Authors' contribution

All authors met the criteria for gaining authorship based on the recommendations of the International Committee of Medical Journal Editors.

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