Original Article

Predicting Factors for Occurrence of Cardiac Arrest in Critical, Emergency and Urgency Patients in an Emergency Department†

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Objective: To identify the predicting factors associated with the occurrence of cardiac arrest in an emergency department (ED).

Materials and Methods: The present research was a retrospective study of all non-traumatic ED patients assigned to emergency severity index (ESI) level 1 (critical), level 2 (emergency), and level 3 (urgency) between August 1, 2014 and July 31, 2016. The primary outcome was the differentiation of predicting factors between cardiac arrest patients and non-cardiac arrest patients for occurrence of cardiac arrest in an ED.

Results: Four hundred eighty patients were enrolled. The factors found to have a significant association ($p<0.05$) in the non-cardiac arrest group versus the cardiac arrest group at the ED were systolic blood pressure (SBP), oxygen saturation (SpO_2), Glasgow coma scale score, normal sinus rhythm, sinus tachycardia, serum pH, serum lactate level, and the modified early warning score (MEWS). A multivariate analysis was then performed. After adjusting for multiple factors, ESI level 2 patients were more likely to have cardiac arrest in the ED compared with ESI level 1 (adjusted odds ratio [ORadj] 1.66, 95% confidence interval [CI] 0.82 to 3.37). Furthermore, ESI level 2 patients were more likely than ESI level 1 patients to have cardiovascular disease (ORadj 1.89, 95% CI 0.87 to 4.11), heart rate lower than 55 beat/minute (ORadj 6.83, 95% CI 2.14 to 21.83), SBP lower than or equal to 90 mmHg (ORadj 3.41, 95% CI 1.53 to 7.56), SpO_2 lower than 94% (ORadj 4.76, 95% CI 2.29 to 9.91), sinus tachycardia (ORadj 4.32, 95% CI 1.77 to 10.51), serum lactate greater than 4 mmol/L (ORadj 10.66, 95% CI 3.68 to 30.87), and MEWS more than 4 (ORadj 4.86, 95% CI 2.44 to 9.67). These factors remained predictive of cardiac arrest at the ED.

Conclusion: The factors related to cardiac arrest in the ED are ESI level 1 and level 2 patients, cardiovascular diseases, SpO_2 lower than 94%, serum lactate level greater than 4 mmol/L, and MEWS more than 4. These factors can be used as an ED's triage and markers to identify the patients who might have a tendency to develop cardiac arrest.

Keywords: Cardiac arrest, Predicting factor, Emergency department

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Cardiac arrest is a major public health problem in many countries. The incidence of cardiac arrest varies from 0.5 to 1.5 per 1,000 people per year[1]. The survival rates for cardiopulmonary resuscitation generally depends on the location of cardiac arrest[2]. In adult patients who suffer from out-of-hospital cardiac arrest (OHCA) and receive resuscitative procedures from an emergency medical system, the survival rates remain low at 10.8%. In-hospital cardiac arrest has a better outcome in the range of 22.3% to 25.5% of adults who survive to discharge[3].

Triage is a tool used to assess and prioritize patients who come to the emergency department (ED). The most purposeful objective of triage is to identify high-risk patients. This tool should be easy, rapid, and non-invasive for early detection of patients who need close monitoring, aggressive resuscitation, and intervention before their clinical conditions worsen

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Table 1. Modified early warning score (MEWS)*

Score	Respiratory rate (breaths/minute)	Heart rate (beats/minute)	Systolic blood pressure (mmHg)	Body Temperature (°C)	AVPU
3	-	-	≤70	-	-
2	≤8	≤40	71 to 80	≤35	-
1	-	41 to 50	81 to 100	35.1 to 36	-
0	9 to 14	51 to 100	101 to 199	36.1 to 38	Alert
1	15 to 20	101 to 110	-	38.1 to 38.5	Reacting to voice
2	21 to 29	111 to 129	≥200	≥38.6	Reacting to pain
3	>29	>129	-	-	Unresponsive

AVPU=alert, voice, pain, unresponsive

* Modified from Nishijima et al[5]

and result in cardiac arrest[4].

The present study aimed to identify factors associated with cardiac arrest, which consisted of the initial vital signs, serum pH, serum lactate level, initial point-of-care testing (POCT) for glucose, and modified early warning score (MEWS). The results of these factors could be used to compare the significance of each factor to predict cardiac arrest and prevent the occurrence of cardiac arrest in the ED. It is important to promptly identify potential cardiac arrest patients in the ED for proper management and care.

Materials and Methods

The present study was an observational, retrospective data collection study between August 1, 2014 and July 31, 2016 of non-traumatic patients aged 18 years and older who were categorized into ESI level 1 to level 3. Songklanagarind Hospital is an urban teaching hospital that has an ED volume of over 48,000 patient visits per year. During the study period, 41,254 ESI level 1 to level 3 patients visited the ED. A computer-based randomization system selected 480 patients, who met the enrollment criteria. The patients who had OHCA were excluded. Ethics approval was obtained from the Institutional Ethics Committee Board of the Faculty of Medicine at Prince of Songkla University.

The following terms and conditions were defined for the present study:

Emergency Severity Index (ESI) is a five-level triage protocol used in the ED to facilitate the prioritization of patients based on the urgency of treatment upon the patient's conditions[4].

ESI level 1 (critical) refers to patients who are the most critically ill and require an immediate life-saving intervention such as CPR, defibrillation, intubation, and chest needle decompression.

ESI level 2 (emergency) refers to a high-risk patient whose condition could easily deteriorate or who presents with symptoms suggestive of conditions that require time sensitive treatment such as active chest pain, severe pain, and signs of stroke.

ESI level 3 (urgency) are stable patients with multiple types of resources needed to investigate or treat, such as lab tests plus x-ray imaging.

ESI level 4 are stable patients with only one type of resource anticipated, such as only an X-ray or only sutures.

ESI level 5 are stable patients with no resources anticipated except oral or topical medications or prescriptions.

The MEWS is a simple physiologic score that aims to detect early abnormalities by grading vital signs (Table 1)[5]. The cerebral performance category (CPC) scale is widely used to assess neurological outcome following cardiac arrest. The CPC score ranges from 1 to 5. Many investigators define a favorable outcome as CPC 1 or 2 and an unfavorable outcome as CPC 3 or more[6].

Outcome measurements

The data consisted of demographics, ESI level, the initial ED vital signs, pupil reaction, and mental status. The patients were divided into cardiac arrest and non-cardiac arrest groups. If the patient was in the cardiac arrest group, the cardiac arrest time was recorded. Initial electrocardiogram (EKG), serum pH, serum lactate, and initial POCT for glucose results were recorded followed by the patients who had an indication. The MEWS was calculated for each patient on admission using the initial physiologic parameters. Neurological outcome using the CPC scale, the place

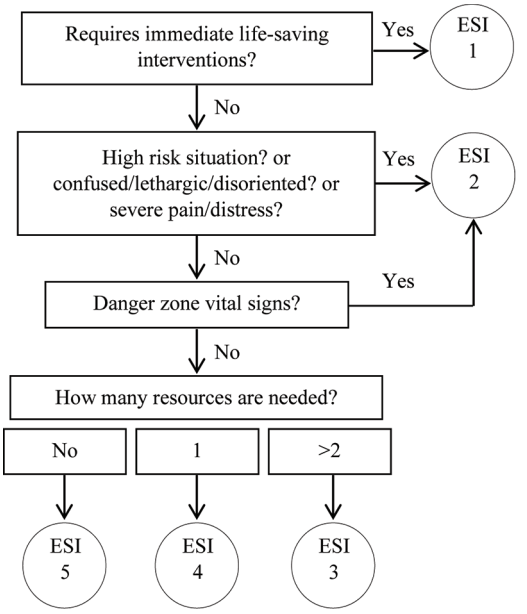

Figure 1. Songklanagarind Triage Protocol (modified from ESI version 4).

of death, mortality rate at three and seven days as well as after seven days of admission were also recorded. The primary outcome variable was the composite of predicting factors of cardiac arrest in the ED. The factors were compared using R software version 3.2.2.

Statistical analysis

The statistical analysis was conducted using R software version 3.2.2. Continuous variables were analyzed and are reported as mean and median, while categorical variables are reported as percentage. The Student t-test was used for continuous and the Pearson's chi-squared test was used for categorical variables. Multivariate logistic regression model was used to evaluate predicting factors for cardiac arrest. The hospital mortality rates at three days and seven days in the cardiac arrest group were also reported. A p-value less than 0.05 was considered statistically significant.

Result

Demographic data

Four hundred eighty patients were included in the present study. There were 265 (55%) men and 216 (45%) women. The baseline characteristics of the enrolled patients are shown in Table 2. The median ages of patients without cardiac arrest and with cardiac arrest were 66.5 and 67.5, respectively. Although patients in cardiac arrest group were 67.5% male, it was not significant difference (p=0.135). The three main diagnosis groupings were respiratory (22.6%), cardiovascular (17.9%), and neurological (16.6%) diseases. Furthermore, the authors found that patients with ESI level 2, ESI level 1, prior renal disease, and taking beta blocker medication were significant higher in the sudden cardiac arrest group.

Predictive factors of cardiac arrest

The vital signs, initial EKG, laboratory values, and MEWS of the patients were measured initially at the ED (Table 3). Significant variables between the cardiac arrest group and non-cardiac arrest group were systolic blood pressure (SBP), oxygen saturation, Glasgow coma scale (GCS) score, normal sinus rhythm, sinus tachycardia, serum pH, serum lactate levels, and MEWS.

A multivariate analysis was performed after adjusting for multiple factors, The ESI level 2 patients were more likely to have cardiac arrest in the ED compared with ESI level 1 patients (adjusted odds ratio [ORadj] 1.66; p<0.001). Furthermore, ESI 2 patients were more likely than ESI level 1 patients to have cardiovascular disease (ORadj 1.89; p=0.01), heart rate lower than 55 bpm (ORadj 6.83; p=0.18), SBP at 90 mmHg or lower (ORadj 3.41; p=0.006), SpO_2 below 94 (ORadj 4.76; p<0.012), sinus tachycardia (ORadj 4.32; p=0.002), lactate of more than 4 mmol/L (ORadj 10.66; p<0.001), and MEWS of more than 4 (ORadj 4.86; p=0.028). These factors remained predictive of cardiac arrest at the ED (Table 4).

Patient outcomes

Forty patients (8.3%) developed cardiac arrest at the ED. In the cardiac arrest group, five patients survived to hospital discharge (12.5%). Twenty-five patients died in the ED (74%), four in the ward (11.4%), and six in the intensive care unit (ICU) (17.1%). Thirty-three patients (94.3%) died within three days. The present study also found that only two patients (5%) had a good neurological outcome (CPC score 1) (Table 5).

Discussion

Deterioration of clinical conditions can occur in the ED at any time. Some physiological variables such as respiratory rate, heart rate, blood pressure, pulse oximetry, serum lactate, and MEWS were used as predictor tools for cardiac arrest in several studies[5,7-10]. A study from Tobias et al assessed pre-hospital lactate levels in medical patients prior to intravenous fluid

Table 2. Demographic and baseline characteristics of patients

Characteristics	Non-cardiac arrest group (n=440) n (%)	Cardiac arrest group (n=40) n (%)	Total (n=480) n (%)	p-value
Demographics				
Age (year), Median (IQR)	66.5 (53, 79)	67.5 (47, 81)	65 (53, 79)	0.896
Sex				0.135
• Male	237 (53.9)	27 (67.5)	264 (55.0)	
• Female	203 (46.1)	13 (32.5)	216 (45.0)	
ESI				0.002
ESI 1	156 (35.5)	14 (35.0)	170 (35.4)	
ESI 2	164 (37.3)	24 (60.0)	188 (39.2)	
ESI 3	120 (27.3)	2 (5.0)	122 (25.4)	
Medical history				1.000
Absent	60 (13.8)	6 (15.0)	66 (13.9)	
Present	375 (86.2)	34 (85.0)	409 (86.1)	
• Diabetes mellitus	105 (28)	11 (32.4)	116 (28.4)	0.730
• Hypertension	161 (42.9)	16 (47.1)	177 (43.3)	0.776
• Dyslipidemia	86 (22.9)	10 (29.4)	96 (23.5)	0.521
• Cardiovascular diseases	95 (25.3)	14 (41.2)	109 (26.7)	0.072
• Renal diseases	46 (12.3)	9 (26.5)	55 (13.4)	0.032
• Respiratory disease	76 (20.3)	9 (26.5)	85 (20.8)	0.527
• Gastrointestinal diseases	37 (9.9)	4 (11.8)	41 (10.0)	0.764
• Stroke	55 (14.7)	6 (17.6)	61 (14.9)	0.829
• Malignancy	84 22.4)	5 (14.7)	89 (21.4)	0.410
• Other	36 (9.6)	6 (17.6)	42 (10.3)	0.142
Diagnosis grouping				
Respiratory	90 (22.0)	11 (29.7)	101 (22.6)	0.384
Cardiovascular	69 (16.9)	11 (29.7)	80 (17.9)	0.084
Neurological	72 (17.6)	2 (5.4)	74 (16.6)	0.093
Gastrointestinal	44 (10.8)	3 (8.1)	47 (10.5)	0.784
Renal	22 (5.4)	3 (8.1)	25 (5.6)	0.452
Endocrine	21 (5.1)	0 (0.0)	21 (4.7)	0.241
Infectious disease	36 (8.8)	2 (5.4)	38 (8.5)	0.758
Malignancy	18 (4.4)	2 (5.4)	20 (4.5)	0.677
Endocrine	40 (9.8)	3 (8.1)	43 (9.6)	1.000
Prior medical therapy				
No medication	325 (76.3)	22 (66.7)	347 (75.6)	0.303
Beta-blockers	66 (65.3)	10 (90.0)	76 (67.9)	0.101
Calcium-channel blockers	48 (47.5)	1 (9.1)	49 (43.8)	0.022
Digoxin	4 (4.0)	0 (0.0)	4 (3.6)	1.000
Amiodarone	5 (5.0)	0 (0.0)	5 (4.5)	1.000

IQR=interquartile range; ESI=Emergency Severity Index

Table 3. Measurements of vital signs, initial EKG, laboratory values, and MEWS of patients

Variable	Non-cardiac arrest group (n=440)	Cardiac arrest group (n=40)	Total (n=480)	p-value
Vital signs, Median (IQR)				
Heart rate	98 (80,116)	90 (67, 116.2)	94 (78, 116)	0.179
Systolic BP (mmHg)	135 (114, 158)	120 (90, 140)	133 (112, 156)	<0.001
Diastolic BP (mmHg)	77 (64.8, 87.2)	74.5 (57.2, 84)	77 (64, 87)	0.220
Respiratory rate	26 (20, 32)	28 (24, 34)	26 (20, 32)	0.504
Temperature (°C)	37 (36.4, 37.2)	36.6 (36, 37.7)	37 (36.3, 37.2)	0.318
Oxygen saturation (%)	97 (89, 98)	82.5(78, 95)	97 (88, 98)	<0.001
Glasgow Coma Scale score	15 (15, 15)	11.5 (8.8, 15)	15 (14, 15)	<0.001
Initial EKG, n (%)	276 (62.7)	30 (75.0)	306 (63.7)	0.169
Sinus tachycardia	60 (21.7)	14 (46.7)	74 (24.2)	0.005
Sinus bradycardia	5 (1.8)	0 (0)	5 (1.6)	1.000
Heart block	3 (1.1)	2 (6.7)	5 (1.6)	0.077
SVT	8 (2.9)	0 (0)	8 (2.6)	1.000
Atrial flutter	2 (0.7)	0 (0)	2 (0.7)	1.000
Atrial fibrillation	27 (9.8)	4 (13.3)	31 (10.1)	0.524
Laboratory values, Median (IQR)				
POCT for glucose (mg%)	121 (93, 168.5)	138 (109, 177)	122 (94.5, 170)	0.292
Arterial blood gas				
• pH	7.4 (7.3, 7.4)	7.2 (7, 7.3)	7.4 (7.3, 7.4)	<0.001
• Lactate	2 (1.1, 4.2)	7 (5, 10.8)	2.4 (1.3, 5.3)	<0.001
MEWS score, Median (IQR)	3 (2, 5)	5 (3, 6)	3 (2, 5)	<0.001

IQR=interquartile range; BP=blood pressure; EKG=electrocardiogram; SVT=supraventricular tachycardia; POCT=point-of-care testing; MEWS=modified early warning score

resuscitation and found that lactate level greater than 2 was associated with hospital mortality[8]. The present study found that the risk factors for cardiac arrest in ED included ESI level 1 and 2, cardiovascular disease, heart rate slower than 55 beats per minute, SBP lower than 90 mmHg, SpO_2 less than 94%, sinus tachycardia, lactate levels greater than 4 mmol/L, and MEWS more than 4. After multivariate analysis, the factors that risk to cardiac arrest in ED were the lactate level, which had the highest OR, followed by the MEWS, and sinus tachycardia. Two previous prospective observational studies and a retrospective cohort study found that a heart rate slower than 55 beats per minute was one of the best vital sign predictors of cardiac arrest in the ED[7,10]. In contrast, the present study found that a heart rate slower than 55 beats per minute had no statistically significant difference.

Importantly, the authors found that serum lactate greater than 4 mmol/L was a significant predictor of cardiac arrest and was ten times more likely to result in cardiac arrest compared with the non-cardiac arrest group. To the authors' knowledge, no study has evaluated the accuracy of lactate to predict cardiac arrest in the ED. The present study was compatible with Tobias et al and Guyette et al[8,9].

ESI level 2 patients were 1.6 times more likely to have cardiac arrest in the ED compared with ESI level 1. It may be because patients with ESI level 1 were more severe and mostly received immediate treatment to prevent cardiac arrest. In addition, ESI level 2 patients were monitored less frequently due to limitation of personnel and equipment. Cardiovascular disease is the risk factor of cardiac arrest in the ED with OR 1.89 (p=0.01). This result is compatible with the study of Ong et al that demonstrated that cardiovascular disease causes a higher rate of ED cardiac arrest[7].

MEWS is a good predictor of cardiac arrest in

Table 4. Multivariate logistic regression analysis of risk factors for cardiac arrest

Variable	Adjusted OR (95% CI)	p-value
ESI (ref. ESI 1)		<0.001
ESI 2	1.66 (0.82 to 3.37)	<0.001
ESI 3	0.19 (0.04 to 0.85)	0.303
Underlying diseases		
Renal diseases	2.55 (1.14 to 5.72)	0.015
Diagnosis grouping		
Cardiovascular	1.89 (0.87 to 4.11)	0.01
Vital signs		
Heart rate (ref. 55 to 110)		0.007
• <55	6.83 (2.14 to 21.83)	0.18
• >110	1.36 (0.66 to 2.79)	0.018
Systolic BP (ref. 91 to 180)		0.006
• ≤90	3.41 (1.53 to 7.56)	0.158
• >180	0.33 (0.04 to 2.51)	0.026
Oxygen saturation (>94 vs. ≤94)	4.76 (2.29 to 9.91)	0.012
Initial EKG (ref. NSR)		
Sinus tachycardia	4.32 (1.77 to 10.51)	0.002
Other	2.56 (0.9 to 7.22)	0.899
Laboratory values		
Lactate (>4 vs. ≤4)	10.66 (3.68 to 30.87)	<0.001
MEWS score (>4 vs. ≤4)	4.86 (2.44 to 9.67)	0.028

OR=odds ratio; CI=confidence interval; ESI=emergency severity index; BP=blood pressure; EKG=electrocardiogram; NSR=normal sinus rhythm; MEWS=modified early warning score

Table 5. Patient outcomes

Outcomes	Non-cardiac arrest group (n=440) n (%)	Cardiac arrest group (n=40) n (%)	Total (n=480) n (%)	p-value
Survive				<0.001
Yes	404 (91.8)	5 (12.5)	409 (85.2)	
No	36 (8.2)	35 (87.5)	71 (14.8)	
CPC score				
CPC 1	-	2 (50.0)	-	
CPC 2	-	0 (0.0)	-	
CPC 3	-	1 (25.0)	-	
CPC 4	-	1 (25.0)	-	
CPC 5	-	0 (0.0)	-	
Place of death				<0.001
ED	0 (0.0)	25 (71.4)	25 (35.2)	
Ward	8 (50.0)	4 (11.4)	22 (31)	
ICU	18 (50.0)	6 (17.1)	24 (33.8)	
Time of death				<0.001
3 days	19 (52.8)	33 (94.3)	52 (73.2)	
4 to 7 days	2 (5.6)	0 (0.0)	2 (2.8)	
After 7 days	15 (41.7)	2 (5.7)	17 (23.9)	
ED disposition				<0.001
General ward	153 (34.8)	2 (5.0)	155 (32.3)	
ICU	37 (8.4)	12 (30.0)	49 (10.2)	
EDOU	35 (8.0)	0 (0.0)	35 (7.3)	
Refer	50 (11.4)	1 (2.5)	51 (10.6)	
Discharge	165 (37.5)	25 (62.5)	190 (39.6)	

CPC=cerebral performance category, ED=emergency department, ICU=intensive care unit, EDOU=emergency department observation unit

the ED. In a prior prospective observational study of critically ill patients, the MEWS score can be used to predict cardiac arrest within 72 hours with sensitivity of 81.4% and specificity of 72.3%, which is similar to the present study[7]. Thus, MEWS can be used as a factor to predict cardiac arrest at the ED.

Churpek et al mentioned that the most accurate individual predictor of cardiac arrest was the maximum respiratory rate[10]. In the current study, there was no difference in the respiratory rates between the two groups, in patients with cardiac arrest versus those with non-cardiac arrest[10]. However, SpO_2 less than 94% at the ED was 4.76 times more likely to lead to cardiac arrest at the ED. SpO_2 should be considered as a predictor of cardiac arrest symptom in the ED.

In terms of patient outcomes, the patient survival rate after cardiac arrest in ED was only 12.5%, which is considered low. The percentage of survivors with good neurological outcome (CPC score 1 or 2) was only 5%. Therefore, the prevention of cardiac arrest with the attempt to resuscitate and carefully monitoring in ED is the most important thing to be considered.

Conclusion

The factors related to cardiac arrest in the ED are ESI level 1 and level 2 patients, cardiovascular diseases, SpO_2 lower than 94%, serum lactate level greater than 4 mmol/L, and MEWS more than 4. These factors can be used as an ED's triage and markers to identify the patients who might have a tendency to

develop cardiac arrest.

What is already known on this topic?

Several studies have shown some physiologic factors that predict cardiac arrest in ED.

What this study adds?

The study shows other factors that predict cardiac arrest patients in ED.

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Compliance with ethical requirements

The institutional ethics committee board approved the present study. The institutional review board of Prince of Songkla University is affiliated with the International Conference on Harmonization in Good Clinical Practice or ICH-GCP protocol. According to our institutional review board protocol for waiver of informed consent, the requirement for consent was waived because the participants had no more than minimal risk and the standard treatment procedure was provided. All research information must be kept as confidential data in an encrypted file with password and limited data access by only the researcher and assistant.

Authors' contributions

Phitchayangkoon A performed the literature search, study design, data collection, data analysis, and data interpretation. Dadeh A did the study design and critical revision and manuscript writing.

Conflicts of interest

The authors declare no conflict of interest.

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