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Clinical paper

Association of sudden in-hospital cardiac arrest with emergency department crowding

Yu-Hsin Chang[a,1], Hong-Mo Shih[a,1], Chih-Yu Chen[a,*], Wei-Kung Chen[a], Fen-Wei Huang[b], Chih-Hsin Muo[c]

[a] Department of Emergency Medicine, China Medical University Hospital, Taichung, Taiwan
[b] Department of Medical Research, China Medical University Hospital, Taichung, Taiwan
[c] Department of Public Health, China Medical University and Management Office for Health Data, China Medical University Hospital, Taichung, Taiwan

Abstract

Background: In Taiwan, emergency department (ED) crowding is inevitable; many studies have investigated the various negative effects of ER crowding on patients. In general, ED crowding reduces patient satisfaction, delays treatment, and increases mortality. However, most studies have focused on the relationship between ED crowding and delay mortality rather than sudden mortality. This study investigates the association of ED crowding with sudden unexpected in-hospital cardiac arrest (IHCA).

Methods: The retrospective observational study recruited patients with sudden IHCA in an ED from February 2016 to September 2017. Exclusion criteria included (1) out-of-hospital cardiac arrest, (2) patient with signed do-not-resuscitate consent, (3) pediatric patient, and (4) trauma patient. ED crowding parameters, including ED bed occupancy rates (EDBORs), number of boarding patients, and patients with boarding time to general ward or intensive care unit of >24 and >48 h, all were recorded every 2 h.

Results: Significant increments were noted in IHCA incidence when EDBOR was >260%, with a rate ratio of 1.50 (95% confidence interval [CI], 1.03–2.17). However, the number of boarding patients was not associated with IHCA incidence ($P > 0.05$). Prolonged boarding time to general ward and ICU of >24 and >48 h both increased the IHCA incidence.

Conclusion: This first study investigating the relationship between ED crowding and sudden IHCA found EDBORs and prolonged boarding to general wards or ICUs were associated with increased sudden IHCA incidence.

Keywords: IHCA, Cardiac arrest, ED, ED crowding, Quality control

Introduction

Emergency department (ED) crowding is an inevitable global phenomenon.[1] In Taiwan, it has resulted from the implementation of National Health Insurance program and easy access to medical resources. ED crowding leads to the deterioration of clinical care, making this a public health problem. Thus far, various studies have investigated the various negative effects of ED crowding on both physicians and patients. For physicians, ED crowding can increase the decision-making time and increase CT and laboratory examination use.[2] Moreover, Pines et al. reported that in patients with community-acquired pneumonia, ED crowding delayed or led to nonreceipt of antibiotics.[3] In addition, ED crowding can delay resuscitation effort.[4,5] For patients, ED crowding can lead to failure to seek consultation and prolonged boarding time and thus reduce patient satisfaction.[6–8] Notably, ED crowding considerably increases mortality during hospital admission.[5,9–12]

* Corresponding author at: Department of Emergency Medicine, China Medical University Hospital, No. 2, Yuh-Der Road, Taichung 40447, Taiwan.
E-mail address: d27974@mail.cmuh.org.tw (C.-Y. Chen).
[1] These authors contributed equally to the work.

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To our knowledge, most studies have focused only on the correlation of ED crowding with mortality over several days after admission, rather than with sudden mortality, such as that through sudden in-hospital cardiac arrest (IHCA). Because ED crowding potentially increases sudden IHCA incidence, we conducted this study to understand the risk factors for sudden IHCA due to ED crowding.

Materials and methods

Study design and participants

In this retrospective observational study, we recruited patients who experienced IHCA during February 2016–September 2017 in the ED of China Medical University Hospital (CMUH). CMHU is a 1700-bed, urban, academic, tertiary care hospital with approximate 150,000 ED visits annually. Our emergency department has 7 beds for trauma patients, 31 beds for medical disease patients, 10 beds for critical ill patient, 1 room for major trauma patient, 1 room for mental health patient and 2 isolation rooms for airborne disease patient. If patient need admission to general ward would transfer to observation room with 28 beds. In 2016, our emergency department had 32 emergency physicians, 15 residents and 75 nurses.CMUH had 24-hour consultants including cardiologists, cardiovascular surgeons, neurosurgeons, neurologists, plastic surgeons and ophthalmologists . . . etc.On average, CMUH monthly receives visits from 27.4, 10.9, and 20.4 patients with acute stroke, ST-elevation myocardial infarction, and major trauma, respectively.

We included all patients with IHCA in the ED during the study period, but excluded those younger than 20 years, those with cardiac arrest before arrival to the ED, and those with a signed do-not-resuscitate consent before the cardiac arrest event. This study was approved by the Institutional Review Board of the China Medical University (CMUH-107-REC1-033).

Data collection and processing

We collected the clinical data of the enrolled patients from our resuscitation record and electronic database. The record of each patient with IHCA is documented by a duty nurse; it contains resuscitation-related information, such as onset time, period, initial rhythm, medications, return of spontaneous circulation status, and procedure performance. Other clinical data, including age, sex, underlying disease, chief complaint, and trauma status, were extracted from the electronic database.

The evaluation of ED crowding is routinely recorded by the nurse every 2 h; the evaluated parameters comprise ED bed occupancy rate (EDBOR), number of boarding patients, boarding time to general ward of >24 and >48 h, and to intensive care unit (ICU) of >24 and >48 h. EDBOR is the ratio of the number of beds occupied by patients to total number of licensed ED beds.

Outcome measures

Our primary outcome was the association between IHCA incidence and ED crowding. The incidence of IHCA is the ratio of the time interval at which IHCA occurs to the total time interval. If a patient experienced more than one episode of IHCA, only the first episode was included. After classifying each time interval and integrating IHCA information, we could calculate the IHCA incidence at different crowding levels in each group.

Primary data analysis

In the descriptive analysis of study ED information, continuous and nominal variables are presented as means ± standard deviations (SDs) and frequencies of occurrence, respectively, and compared using independent sample *t* and chi-square tests, respectively. ED crowding evaluation parameters are also presented as means ± SDs; moreover, to compare nonparametric variables of ED crowding, we applied the chi-square test.

According to the degree of parameter, we classified each group of EDBOR, total number of boarding patients, and boarding time to general ward of >24 and >48 h into three different levels (low, middle and high), such that close to the nearest tertile. In addition, because prolonged boarding to ICU was rare in our hospital, only two levels were categorized (low and high). Finally, the relationship between the incidence of IHCA and degree of ED crowding was calculated as the relative risk (RR). All statistical assessments were two-sided; a *P* of <0.05 was considered statistically significant.

Results

During the study period (February 2016–September 2017), 275,521 ED visits, 30,645 patient sent by emergency medical service system and 6293 patient transferred from other hospital were recorded; 6403 and patients were admitted to ICU and general ward, respectively. Of them, 1033 were cardiac arrest patients were identified; after excluding 855 patients with pre-hospital cardiac arrest, 178 patients with IHCA in the ED were enrolled (Table 1).

Table 2 presents the average IHCA distribution and mean ED crowding parameters daily. There were 2 patient data was missing and total 176 patient were enrolled. According to the levels of each ED crowding parameter, 6876 time intervals (573 days × 12 interval) were classified into groups to evaluate the association between ED crowding and IHCA incidence (Table 3). For EDBORs of >260%, 200%–260%, and <200%, 2553, 2389, and 1994 time intervals were noted, respectively. Significant increments in IHCA incidence were noted when EDBORs were >260%, with a rate ratio (95% CI) of 1.50 (1.03–2.17). The total number of boarding patients was not associated with IHCA incidence ($P > 0.05$); nevertheless, an increasing trend was noted.

Prolonged boarding to general ward of both >24 and >48 h lead to higher IHCA incidence, with rate ratios (95% CIs) of 1.64 (1.15–2.35) and 1.53 (1.10–2.12), respectively. In the prolonged ICU-boarding subset, increased incidence of cardiac arrest was noted if more than one patient had a boarding time of >24 and >48 h (RRs [95% CIs], 1.42 [1.04–1.95] and 1.61 [1.16–2.23], respectively).

Discussion

In this study, we found that ED crowding can increase IHCA risk. Several validated parameters, which would increase IHCA incidence, were applied to evaluate crowding condition every 2 h. The EDBORs and prolonged boarding time of >24 or >48 h also increased IHCA incidence. To our knowledge, this is the first study highlighting the association between the ED crowding and sudden IHCA.

Here, sudden IHCA in the ED was considered the primary outcome measurement. Jo et al. reported that higher ED occupancy rates (EDOR) are positively correlated with early (1–3-day) mortality even after control of

Table 1 – ED baseline information.

		Total	Mean ± SD	%
ED visit		275521	13776.05 ± 1245.87	
Visit group	Trauma	63465	3173.25 ± 171.83	23.29
	Non-trauma (adult)	157895	7894.75 ± 825.14	57.93
	Non-trauma (pediatric)	51186	2559.3 ± 489.5	18.78
Transferred	Hospital	6293	314.65 ± 27.78	17.04
	Emergency medical service	30645	1532.25 ± 58.46	82.96
Admission	General ward	49448	2472.4 ± 153.47	88.54
	ICU	6403	320.15 ± 18.43	11.46
Cardiac arrest	Pre-hospital	855	42.75 ± 10.35	
	In-hospital	178	8.9 ± 3.6	
Acute stroke		548	27.4 ± 7.49	
STEMI		218	10.9 ± 3.63	
Major trauma		408	20.4 ± 4.67	
Triage acuity	Immediate	9594	479.7 ± 52.89	3.48
	Emergent	43710	2185.5 ± 248.78	15.86
	Urgent	187972	9398.6 ± 926.52	68.22
Age			38.9 ± 0.91	
Sex	Male	134987		48.99
	Female	140534		51.01

ED = emergency department, ICU = intensive care unit, STEMI = ST-elevation myocardial infarction.

Table 2 – The distribution of ED crowding.

Time (o'clock)	Unexpected CA (n, %)	Total Pt in ED (n,SD)	EDBOR (%)	Pt waiting for boarding (n,SD)	Pt with T_b >24 h to ward (n, SD)	Pt with T_b >48 h to ward (n, SD)	Pt with T_b >24 h to ICU (n, SD)	Pt with T_b >48 h to ICU (n, SD)
1–2	13 (7.39)	105.7 (27.5)	211	48.8 (20.3)	9.39 (8.22)	4.35 (4.59)	0.44 (1.48)	0.22 (0.83)
3–4	14 (7.95)	105.6 (46.5)	211	53.8 (41.9)	10.5 (12.1)	4.74 (4.11)	0.47 (1.47)	0.23 (0.81)
5–6	12 (6.82)	104.1 (22.6)	208	55.5 (43.5)	9.78 (6.15)	4.89 (6.04)	0.48 (1.45)	0.24 (0.78)
7–8	12 (6.82)	104.0 (21.5)	208	57.6 (39.9)	10.3 (8.36)	5.01 (3.99)	0.51 (1.46)	0.25 (0.81)
9–10	15 (8.52)	108.0 (20.3)	216	53.3 (17.7)	10.7 (8.48)	5.45 (6.62)	0.63 (1.64)	0.32 (1.14)
11–12	11 (6.25)	117.6 (20.7)	235	52.2 (42.9)	9.28 (5.31)	4.94 (5.10)	0.50 (0.94)	0.23 (0.57)
13–14	16 (9.09)	121.0 (24.5)	242	47.3 (33.0)	9.04 (10.9)	4.74 (8.24)	0.57 (1.33)	0.22 (0.71)
15–16	11 (6.25)	117.7 (31.6)	234	41.6 (22.4)	7.70 (5.22)	3.98 (5.84)	0.47 (1.09)	0.21 (0.64)
17–18	19 (10.8)	116.8 (30.7)	233	41.2 (33.1)	7.81 (5.55)	3.79 (3.59)	0.43 (0.98)	0.18 (0.61)
19–20	20 (11.4)	120.8 (30.4)	241	41.1 (33.7)	8.01 (5.24)	3.70 (3.29)	0.38 (1.07)	0.17 (0.61)
21–22	17 (9.66)	129.8 (44.8)	260	42.6 (25.8)	8.52 (5.78)	3.94 (3.43)	0.40 (1.01)	0.19 (0.78)
23–24	16 (9.09)	122.6 (34.2)	245	46.5 (29.3)	9.65 (10.4)	4.64 (8.76)	0.52 (1.39)	0.20 (0.85)

IHCA = In-hospital cardiac arrest, EDBOR = Emergency department bed occupancy rate, ED = Emergency department, Pt = patient, T_b = Boarding time, ICU = intensive care unit.

the variables[13] and also indicated that EDORs were associated with increased inpatient mortality in critically ill patients.[11] Most studies have regarded subsequent mortality during admission or short-term period after presentation as an outcome measurement.[9,14] However, we considered sudden IHCA in the ED to represent ED care quality and noted that ED crowding threatened patient safety at a particular instance.

The higher the EDBORs, the more is the number of patients requiring bedrest in the ED, which is associated with increased IHCA risk. No single parameter precisely defining ED crowding is available. Although several studies have compared different parameters and formulas, consensus regarding the varied study designs is lacking.[15,16] In 2008, McCarthy et al. introduced the EDOR as a simple parameter for assessing ED crowding. The EDOR is the ratio of total number of ED patients to the number of licensed beds in ED. Many studies have investigated the relationship between ED crowding and its clinical impact by using this measure.[4,13,17,18] However, in the current study most bed-occupying patients exhibited were immobilized and highly sick, all of which warranted increased attention and care. Therefore, we used the EDBOR, rather than the EDOR, to measure ED crowding. We presumed that because bed-occupying patients may require relatively more nurse and physician care, an overwhelmingly high EDBOR can indicate a higher risk of IHCA in the ED, as observed here.

No significant relationship was noted between total number of boarding patients and IHCA. In our emergency room, except for critically ill patients who need to be admitted to the ICU as soon as possible, other patients can only wait for admission after being stable and diagnosed clearly. We speculated that physicians require less time for examination and decision-making for these patients to arrive at a clear diagnosis and transfer were further required. Therefore, although the number of boarding patients and thus consumed less care capacity, IHCA incidence did not increase significantly among these patients. The EDBOR may be the parameter most representative for ED burden, which was strongly associated with IHCA risk.

This study has several limitations. First, this is a retrospective study in single centered; thus, the generalizability of our results warrants validation studies. Second, we focused only on the relationship between ED crowding and IHCA incidence. The

Table 3 – Analysis for ED crowding index and unexpected cardiac arrest.

ED crowding index		Number of time interval (n)	IHCA (n, %)	RR (95% CI)	p-Value
EDBOR (%)	<200	1934	42 (2.17)	Ref.	
	200–260	2389	51 (2.13)	0.98 (0.65–1.48)	0.9345
	>260	2553	83 (3.25)	1.50 (1.03–2.17)	0.0331
Pt waiting for	0–40	2127	50 (2.35)	Ref.	
Boarding (n)	41–60	2296	47 (2.05)	0.87 (0.58–1.30)	0.4959
	>60	2453	79 (3.22)	1.37 (0.96–1.95)	0.0815
Pt with T_b >24 h to ward (n)	0–7	2525	53 (2.10)	Ref.	
	8–14	2349	54 (2.30)	1.09 (0.75–1.60)	0.6381
	>15	2002	69 (3.45)	1.64 (1.15-2.35)	0.0066
Pt with T_b >48 h to ward (n)	0–3	2964	67 (2.26)	Ref.	
	4–7	1652	31 (1.88)	0.83 (0.54–1.27)	0.3915
	>7	2260	78 (3.45)	1.53 (1.10–2.12)	0.0111
Pt with T_b >24 h to ICU (n)	0–1	5111	118 (2.31)	Ref.	
	>1	1765	58 (3.29)	1.42 (1.04–1.95)	0.0277
Pt with T_b >48 h to ICU (n)	0-1	5545	127 (2.29)	Ref.	
	>1	1331	49 (3.68)	1.61 (1.16–2.23)	0.0048

ED = Emergency department, EDBOR = Emergency department bed occupancy rate, IHCA = In-hospital cardiac arrest, Pt = patient, T_b = Boarding time, RR = Relative risk, ICU = intensive care unit.

confounding factors, such as underlying disease, age, and sex, were not included in the statistical analysis. Although IHCA incidence was based on time intervals, rather than populations, the uncontrolled factors may contribute to some degree of bias. Finally, we did not adjust each IHCA incidence for the total population during the time interval; therefore, our results should be interpreted cautiously.

Conclusion

This is the first study to investigate the relationship between ED crowding and sudden IHCA. High EDBORs and prolonged boarding time in general ward or ICU increased the IHCA incidence. Additional studies with prospective registries of ED crowding parameters and detailed IHCA incidence are required to clarify the association between IHCA and ED crowding.

Conflict of interest

None declared.

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