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The crowd-out effect of a mass casualty incident
Experience from a dust explosion with multiple burn injuries

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Abstract

A mass casualty incident (MCI) can have an enormous impact on an already crowded emergency department (ED), affecting the quality of health care provided to non-MCI ED patients. On June 26, 2015, a burn MCI (BMCI) occurred due to a cornstarch explosion at a party at a water park. The competing needs of the BMCI patients might have crowded out the needs of the non-BMCI patients. Although crowd-out effects have been previously documented in a variety of health care situations, they have not been extensively evaluated during MCIs. We aimed to determine whether the outcomes of the non-MCI patients were compromised during this incident.

We conducted a retrospective observational study comparing several health care parameters and outcomes between non-BMCI patients and historical controls during the designated period using institutional electronic records and the National Health Insurance Research Database.

On the night of the incident, 53 patients were sent to our ED; most of them arrived within 3 hours after the BMCI. There was a significant increase in the wait time for ICU beds among non-BMCI patients compared to the wait times during the corresponding week of the previous year (8.09 ± 4.21 hours vs 3.77 ± 2.15 hours, $P = .008$). At the hospital level, there was a significantly increased length of hospital stay (LOS) in the ICU after the MCI compared with the LOS in the ICU in the same week of the preceding year (median days: 15 vs 8, $P \leq .001$). At the regional level, there were no significant differences between the 2 periods in the LOS in acute care, LOS in the ICU or mortality rates at the involved medical centers.

Crowd-out effects from the MCI occurred in the ED and at the institutional level. Although there was an increased wait time for admission to the ICU and a longer LOS in the ICU, the LOS in acute care beds, treatment of time-sensitive diseases, and mortality rates were not compromised by the current MCI protocol at either the institutional or regional levels.

Abbreviations: BMCI = burn mass casualty incident, ED = emergency department, ICD-9-CM = International Classification of Diseases, 9th Revision, Clinical Modification, ICU = intensive care unit, LBTC = leaving before treatment completion, LOS = length of hospital stay, NHIRD = National Health Insurance Research Database, PPCI = primary percutaneous coronary interventions, STEMI = ST-segment elevation myocardial infarction, TBSA = total body surface area, TTAS = Taiwan Triage and Acuity Scale.

Keywords: burn, crowd-out effect, dust explosion, mass casualty incident, Taiwan

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Key point

- Non-MCI patients experienced some compromised health care index as a result of the crowd-out effect of the influx of MCI patients at the ED and hospital levels under current surge capacity in Taipei city.

1. Introduction

An emergency department (ED) should always be prepared for mass casualty incidents (MCIs). An MCI can have an enormous impact on an already crowded ED and can affect the quality of the health care that non-MCI ED patients receive. A burn MCI (BMCI) developed at Formosa Fun water park due to a cornstarch explosion, and 499 victims from among the more than 4000 "Color Fun" party attendees suffered injuries from severe burns and smoke inhalation.[1] Eventually, this BMCI caused 15 deaths.[2] The extremely low mortality rate of patients with high total body surface area (TBSA) burn injuries resulting from this MCI has been attributed to several crucial factors, including centralization of the emergency response, and resource allocation.[3] Overcrowded EDs hinder the ability of hospitals to handle demand surges during crises and to properly prioritize treatment on the basis of urgency.[1] The competing demands of these tragic incidents can overstretch limited medical resources and potentially result in a reduction in the quality of health care delivered to non-MCI ED patients. Crowd-out effects have been evaluated in other health care settings, such as health insurance, long-term care, and tuberculosis and HIV treatment.[4–5] However, crowd-out effects have not been thoroughly evaluated during MCIs, and few studies have investigated whether the patient surge from an MCI adversely affects non-MCI ED patients.

Therefore, we aimed to determine whether the health care received by non-MCI patients and their outcomes were compromised by the crowd-out effect of the influx of BMCI patients at the ED, hospital (a single tertiary referral medical center), and regional levels.

2. Materials and methods

2.1. Patients

Tri-Service General Hospital (TSGH) is a tertiary referral medical center with 1320 acute care beds, including 120 ICU beds. Approximately 300 patients visit the ED on a daily basis. The TSGH institutional review board for human investigations approved this study and waived the requirement for informed consent because the medical records were deidentified and the study was retrospective in nature.

At the ED level, we conducted a retrospective observational study of consecutive non-BMCI patients who were admitted to the ED between June 27, 2015 and July 3, 2015. The patients seen during the corresponding week of the previous year (June 28, 2014–July 5, 2014) served as historical controls. Data regarding unplanned reattendance within 72 hours, leaving before treatment completion (LBTC), ED admission for >24 hours and >48 hours and the wait times for acute care and ICU beds were retrieved.[6]

At the institutional level, we conducted a retrospective observational study of consecutive non-BMCI patients who were admitted to the hospital between June 27, 2015 and July 26, 2015, with patients seen during the corresponding month of the previous year (June 28, 2014– July 27, 2014) serving as historical controls. The length of hospital stay (LOS) and mortality rate were determined. Two time-sensitive conditions, namely, ST-segment elevation myocardial infarction (STEMI) requiring timely primary percutaneous coronary interventions (PPCI, door-to-balloon time within 90 minutes) and acute ischemic stroke eligible for intravenous thrombolytic therapy (door-to-needle time within 60 minutes), were also considered as measurements of the quality of the health care provided.

At the regional level, we used the National Health Insurance Research Database (NHIRD), which contains outpatient and inpatient claims for all beneficiaries enrolled in Taiwan's mandatory National Health Insurance (NHI) program, to study the possible effects of the event. The NHI serves more than 99% of the Taiwanese population (more than 23 million people). The NHIRD contains patient identification numbers, birthdays, genders, dates of admission and discharge, ICD-9-CM (International Classification of Diseases, 9th Revision, Clinical Modification) diagnostic codes (up to 5 per patient) and outcomes. Previous studies have validated the accuracy of the diagnoses of major diseases, such as acute coronary syndrome and stroke, reported in the NHIRD.[7] This investigation included study and comparison cohorts. The LOSs in acute care and ICU beds and mortality rates were determined. This study was approved by the Institutional Review Board of TSGH at the National Defense Medical Center in Taipei, Taiwan.

2.2. Statistical analysis

Continuous data are expressed as the means±standard deviations and were analyzed using a two-tailed Student's t test. Skewed data are expressed as medians and interquartile ranges. Categorical data were evaluated using the Chi-Squared test or Fisher exact test, and the results are expressed as frequencies (%).[8] The data were analyzed with the Statistical Package for the Social Sciences statistical software, version 22.0 (SPSS, Inc., Chicago, IL, USA).

3. Results

3.1. Patient demographic data

Due to the BMCI, more than 50 patients were sent to our ED, and most arrived within 3 hours (Fig. 1). Eventually, TSGH received 65 (65/499 13%) of the BMCI patients, 31 of whom had TBSA>40% and 4 of whom had TBSA>80%. The MCI protocol was fully activated once more than 20 patients were expected. Twenty patients were admitted to the ICU, and the remaining 33 patients were admitted to the burn or acute care ward. The mortality rate was 0% at TSGH. The characteristics of the ED patients during the BMCI event and those seen during the corresponding period of the previous year, who served as historical controls, are shown in Table 1. Compared with the historical controls, fewer patients were seen in the ED after the BMCI; however, there was a significant increase in the number of patients at levels 1 and 2 of the Taiwan Triage and Acuity Scale (TTAS) and a decrease in the number of patients at TTAS levels 3 to 5. Compared with the corresponding period of the previous year, there was also a significant decrease in the number of ambulance arrivals after the BMCI. At the ED level, the waiting
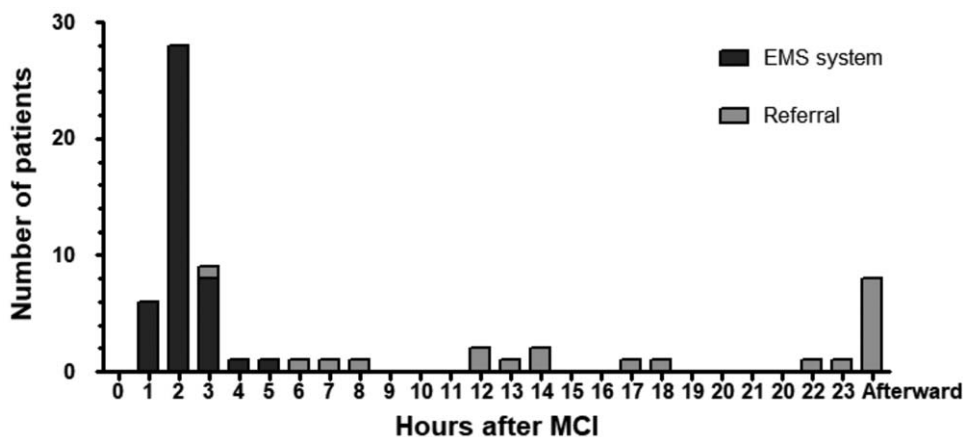
Figure 1. Distribution of the BMCI patients arriving at the ED. BMCI = burn mass casualty incident, ED = emergency department.

period for admission to the ICU for non-BMCI patients was significantly longer than it was during the corresponding weekend of the previous year (8.09 ± 4.21 vs 3.77 ± 2.15 hours, $P = .008$). However, there were no significant differences in

Table 1

Demographic data for the ED patients during the designated period.

	2014.6.28 2014.7.05	2015.6.27 2015.7.04	P value
Total number of ED patients	2291	2046	
Average daily number of ED patients	286.4 ± 33.4	255.8 ± 57.4	
Taiwan Triage and Acuity Scale			
Level 1	57 (2.5%)	114 (5.8%)	<.001*
Level 2	216 (9.4%)	350 (17.1%)	<.001*
Level 3	1553 (67.8%)	1,476 (72.1%)	.002*
Level 4 & 5	436 (19%)	106 (5.2%)	<.001*
Ambulance arrivals	302 (13.2%)	336 (16.4%)	.003*
OHCAs	8 (0.4%)	4 (0.2%)	.336
Transfers in	53 (2.3%)	49 (2.4%)	.860
Transfers out	1 (0.04%)	1 (0.05%)	.936
Admissions to acute care bed	385 (16.8%)	384 (18.8%)	.091
Admissions to ICU	51 (2.2%)	43 (2.1%)	.779

ED = emergency department, ICU = intensive care unit, OHCA = out-of-hospital cardiac arrest.
* $P < .05$.

Table 2

Comparison between the non-BMCI ED patients seen one week after the BMCI and the ED patients seen during the corresponding period of the previous year.

	2014.6.28–7.5	2015.6.27–7.4	P value
Unplanned return within 72 hours	5.09 ± 2.14	3.46 ± 1.63	.168
Left before treatment complete	3.87 ± 1.70	3.90 ± 1.55	.746
Observation time > 24 hours	1.26 ± 1.18	1.55 ± 1.31	.736
Observation time > 48 hours	0.08 ± 0.16	0.10 ± 0.21	.692
Waiting period for acute care bed (hours)	4.55 ± 2.10	4.78 ± 2.39	.133
Waiting period for ICU (hours)	3.77 ± 2.15	8.09 ± 4.21	.008*

ICU = intensive care unit.
* $P < .05$.

unplanned returns to the ED within 72 hours, the number of patients LBTC, the numbers of patients under observation for 24 hours and 48 hours or wait times for acute care beds between the 2 periods (Table 2). As shown in Figure 2, the effect of the BMCI on the wait time for an ICU bed lasted for 1 week.

At the hospital level, the median LOS in the ICU was significantly longer after the BMCI than during the same weekend of the previous year (median days: 8 vs 15, $P \leq .001$). There were no differences between the 2 periods in the LOS in acute care or the mortality rates of patients in acute care and the ICU (Table 3). At the regional level, there were no significant differences between the 2 periods in the LOSs or the mortality rates of patients admitted to either acute care or the ICU in the Taipei region (Table 4).

4. Discussion

We demonstrated that at the institutional level, the BMCI had a crowd-out effect on non-BMCI ED patients, increasing the wait time for an ICU bed for non-BMCI ED patients and increasing the LOS in the ICU. Appropriate MCI protocols, adequate surge capacities and patient flow regulation can minimize the impact of a BMCI on several health care parameters at the ED, institutional, and regional levels.
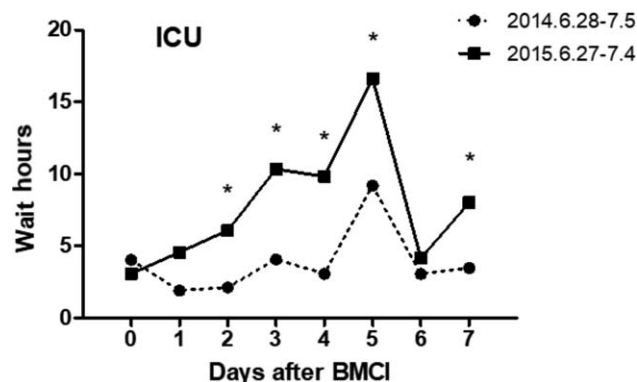

Figure 2. Wait time for the ICU. ICU = intensive care unit.

Table 3

Comparison between the hospitalized patients seen 4 weeks after the BMCI and those seen during the corresponding period of the previous year at a single institution.

	2014.6.28–7.27	2015.6.27–7.26	*P* value
LOS in acute care bed (days)	5 (3–11)	5 (2–10)	.203
LOS in ICU (days)	8 (4–14)	15 (4–21)	<.001*
Mortality rate of patients in acute care	1.98% (85/4294)	2.44% (95/3878)	.866
Mortality rate of patients in the ICU	14.50% (39/269)	13.96% (31/222)	.157
STEMI (n)	3	4	
Door-to-balloon time (minutes)	57.33 ± 28.02	65 ± 25.73	.310
< 90 minutes	100%	100%	1
AIS (n)	52	49	
rt-PA administration rate	1.9% (1/52)	2.0% (1/49)	.966
Door-to-needle times (minutes)	40	48	
Complications	100% (1/1)	0% (0/1)	

AIS = acute ischemic stroke, ICU = intensive care unit, LOS = length of stay, rt-PA = recombinant tissue plasminogen activator, STEMI = ST-segment elevation myocardial infarction.
* $P < .05$.

After the BMCI, there were competing demands between the BMCI and non-BMCI ED patients. MCI protocols specifically aim to prioritize MCI patients and can introduce conflict (in terms of opportunity costs and ethical principles of fairness) into the distribution of limited resources between specific groups of patients. The surge of fifty severely burned patients superimposed on a daily ED volume of 300 patients resulted in increased wait times for the ICU and increased LOSs at our institution. Wait time is the result of maladjustment between the inflow of new patients and the provision of care.[9] Changes in the health care policy regarding wait times guaranteeing that severity is the primary determinant can lead to a crowd-out effect and a debate regarding ethical principles.[9] The crowd-out effect has been well established in several domains of health care, including health insurance,[4] infectious disease treatment in settings with medical resource shortages,[10,11] ethical issues in the implementation of new health policies[9] and the treatment of depression in patients with cancer.[12] Financially, the cost to patients averages USD 1035 per TBSA%, with an average total cost of USD 50,415.[13] The cost of treatment for BMCI patients might also have had an indirect effect on the governmental health insurance system. Studies have shown that a prolonged LOS at an ED is independently associated with an increased risk of in-hospital mortality in critically ill patients, even in those without time-sensitive diseases requiring ICU admission such as severe sepsis or septic shock.[14,15] Increased LOSs in acute care beds and the ICU could increase the financial burden, decrease health-related quality of life and increase the risks of developing complications such as hospital-acquired infections and ICU-acquired weakness.[16,17] We assume that the committed

and organized support gained by following the MCI protocol could minimize the impacts on the EDs and hospitals. Shortages of medical resources could be expected to worsen the effects of the surge of competing demands.

We speculate that an effective MCI protocol and efficient regulation of patient flow could reduce the crowd-out effect on non-MCI ED patients. At the ED, hospital and regional levels, adequate preparation, including practical and detailed planning, and the implementation of disaster drills, is crucial for handling MCIs. Diverting relatively less-acute patients to supporting facilities could also effectively decrease the load on the receiving hospitals. The significant decrease in the number of TTAS level 3 to 5 patients seen in our ED during the critical period after the BMCI could be due to effective diversion of less-critical patients that alleviated the competing demands. Previous disaster planning drills facilitated a quick institutional response directed by the ED physician in charge. An efficient first response, experienced triage, the implementation of a transportation and resource allocation plan, the administration of burn-centered multidisciplinary care and hospital-government cooperation can help reduce in-hospital mortality and further improve the efficacy of the response to the BMCI.[18] Independent surgical and wound care teams were mobilized and assigned to the ED, burn wards and ICUs during the acute phase after the BMCI. When disaster victims need hospitalization for extended periods, adjustments such as transferring stabilized patients to community clinics may be necessary to ensure adequate care for all patients.[1] A core strategy for addressing BMCIs is the implementation of an immediate bed availability approach.[19] A 56-bed acute care ward was rapidly converted into a burn ward, which allowed us to accommodate the surge in BMCI patients within the limited space available. Accumulated experience from previous disasters and MCIs can further improve protocols for future disasters.[20] At the regional level, a centralized MCI protocol guided resource allocation and provided good support for the hospital. Under the Mass Casualty Mechanism of the Ministry of Health and Welfare, nearly 300 emergency vehicles and 1235 first responders were dispatched from fire and health departments across 5 cities and counties. Within 6 hours, 499 victims were delivered to 34 hospitals.[1] This closely linked MCI response mechanism, along with surges in pre- and posthospital medical care and hospital capacities motivated by the health authorities, contributed to the effective and efficient handling of the acute phase of this BMCI.[2,3]

Table 4

Comparison between hospitalized patients seen 4 weeks after the BMCI and those seen during the corresponding period of the previous year in the Taipei region.

	2014.6.28–7.27	2015.6.27–7.26	*P* value
LOS in the acute care ward (days)	8.23 ± 10.39	8.20 ± 10.33	.716
LOS in the ICU (days)	8.19 ± 10.31	8.16 ± 10.24	.685
Mortality rate among patients in the acute care ward	2.31%	2.39%	.912
Mortality rate among patients in the ICU	2.1%	2.2%	.956

ICU = intensive care unit, LOS = length of stay.

There were several limitations in this retrospective study. First, some patients were diverted to other hospitals by the centralized dispatch center. This diversion might have changed the acuity and triage levels, thereby influencing several parameters at a single institution. Nonetheless, there was no significant differences in the LOSs and mortality rates at the regional level between the BMCI and historical control periods. Additionally, the health care parameters investigated might not be reflective of the actual impact of the event, and the results cannot be generalized because of differences in government policies and emergency response system settings. The long-term effects of MCIs on the health care system should also be further evaluated.

5. Conclusion

The crowd-out effect of the MCI was evident at the ED and institutional levels. Compared with the historical control period, after the BMCI, there was an increased wait time for admission to the ICU and a longer LOS in the ICU. Nonetheless, the LOS in acute care beds, treatment of time-sensitive diseases and mortality rates were not compromised at either the institutional or regional levels under the current MCI protocols.

Author contributions

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