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Original Article

Review of Emergency Response Management of 33 Major Burn Victims of the Formosa Fun Coast Dust Explosion Disaster in a Regional Hospital Without Burn Units

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Background: The Formosa Fun Coast Dust Explosion is one of the major national disasters in Taiwan. The Taipei City Hospital (TCH), a regional hospital without a burn unit, received 33 patients out of 499 casualties in the initial response period. This retrospective study aimed to review the primary response of TCH and the outcome and mortality of the patients who were initially managed at TCH.
Methods: Basic profiles, total body surface area (TBSA) with burn injury, facial burn injury, vital signs, laboratory data, intubation rate and clinical outcomes, such as urine output and mortality, were analyzed. Moreover, the emergency department (ED) response faculties, who were involved in the initial response, were interviewed about the critical decision-making processes during the patient surge in the ED.
Results: The average initial estimated TBSA with burn injury in ED was 34.2%, and the average final TBSA assessed in the intensive care unit was 41.0%. The patients with facial burn injury were 38.7%, and the intubation rate was 22.6%. When comparing the result of TCH to the patient group transferred directly to Chang Gung Memorial Hospital (CGMH), and the group received by CGMH from other hospital, the mortality rate was 0.0, 5.7, 9.1%; and the delayed intubation rate was 3.0, 14.3, 27.3%, respectively. The key elements for efficient initial response were the multidisciplinary response team cooperated as a production line, using the clipboards for orders recordings, and the plastic surgeons ED-operating room (OR) direct transferring.
Conclusions: Regarding airway complications, and mortality, patients who were initially managed in TCH had comparable results with patients directly sent to the burn centers. This study supports the notion that immediate resuscitation in multiple level of hospitals, even without burn units but with adequate recruited response personnel, provided the best chance for the survival of casualties during such national disasters.

Key words: *Formosa Fun Coast Dust Explosion, emergency response, disaster, major burn injury, mass casualty incident*

Introduction

On June 27, 2015, a "color play" event at the Formosa Fun Coast waterpark in New Taipei City, Taiwan, attracted hundreds of people who danced in an overcrowded, drained-out swimming pool at sunset. A sudden explosion of colored powder brought a raging fire that burned the participants in the swimming

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pool who had only scarce clothing. Within six hours, 499 victims were delivered to 34 hospitals by the emergency response services (EMS).[1] Due to the inflammable swimwear materials and sticky flamed dust, most of the patients were major burn casualties (the average total body surface area [TBSA] with burn injury was 44%) and required immediate resuscitation. The medical facilities with adequate burn units and staffs were far less than the number of mass casualties.

The Zhong-Xing branch of the Taipei City Hospital (TCH), located 20 km south from the scene of the accident (Fig. 1), is a regional teaching hospital with 296 beds for acute illness but without burn units. The annual emergency visit is around 30,000. One-hundred and twenty-two minutes after the accident, this branch encountered their first patient with major burns brought from the incident by the EMS ambulance (Fig. 2). Thirty minutes later, a minibus loaded with 17 casualties arrived, leading to a patient surge which plunged the emergency department (ED) into chaos (Fig. 3). The Zhong-Xing branch received a total of 21 patients during the event and activated mass casualty incident (MCI) code due to the patient surge. The faculties of ED responded promptly and organized the recruited fellows to manage these patients. The patients were then admitted to the ward, intensive care unit (ICU), distributed to other branches of TCH, or transferred to other medical centers within several days. Moreover, along with the Zhong-Xing branch, four other branches simultaneously received 12 victims of this incident.

As the mortality gradually increased after the event, the primary response managing ability of hospitals without burn units was called into question by the public. This retrospective study is aimed to review the primary response of TCH and the outcome of the patients who were managed initially in TCH as well as to understand the correlation between mortality and the level of initial response at the hospital. Simultaneously, the experiences of the medical response faculties during this incident were also reviewed to improve the response to mass casualties in the future.

Methods

TCH is a community-based, regional, municipal hospital with seven branches in Taipei, Taiwan, 2,930 beds for acute care, and over 15,000 ED visits per year. Nevertheless, there is no burn unit available at this level of hospital.[2] The patients admitted to TCH in the incident were dispatched by the EMS system of

Fig. 1. The geographic relationship between Formosa Fun Coast and Taipei City Hospital, Zhong-Xing branch.

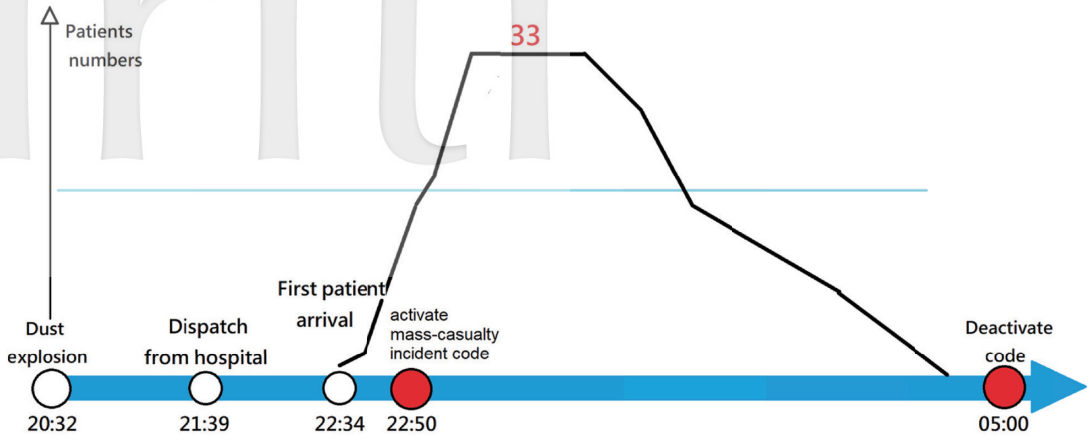

Fig. 2. The patient flow timeline of the emergency department.

Fig. 3. The patient surge picture as the minibus arrived at the emergency department of Zhong-Xing branch.

the Taiwan Ministry of Health and Welfare. Accordingly, 33 patients were admitted to the ED among the five branches of TCH during the initial response to the event. We retrospectively reviewed electronic and paper patient medical records. However, two of the 33 patients, whose medical records were missing, were excluded from the study (Fig. 4). Characteristics of the patients, including age, sex, body weight, TBSA with burn injury, presence of facial burn, vital signs, laboratory data, intubation rate in the ED, vasopressor usage, fluid amount for resuscitation, and clinical outcome, such as urine output and mortality were analyzed.

To reflect the initial response in the ED of TCH, we interviewed the ED response faculties who were involved in the initial response. The critical decision-making processes were recorded and reviewed for assessing the difficulties of management of this rare MCI event at a regional hospital level.

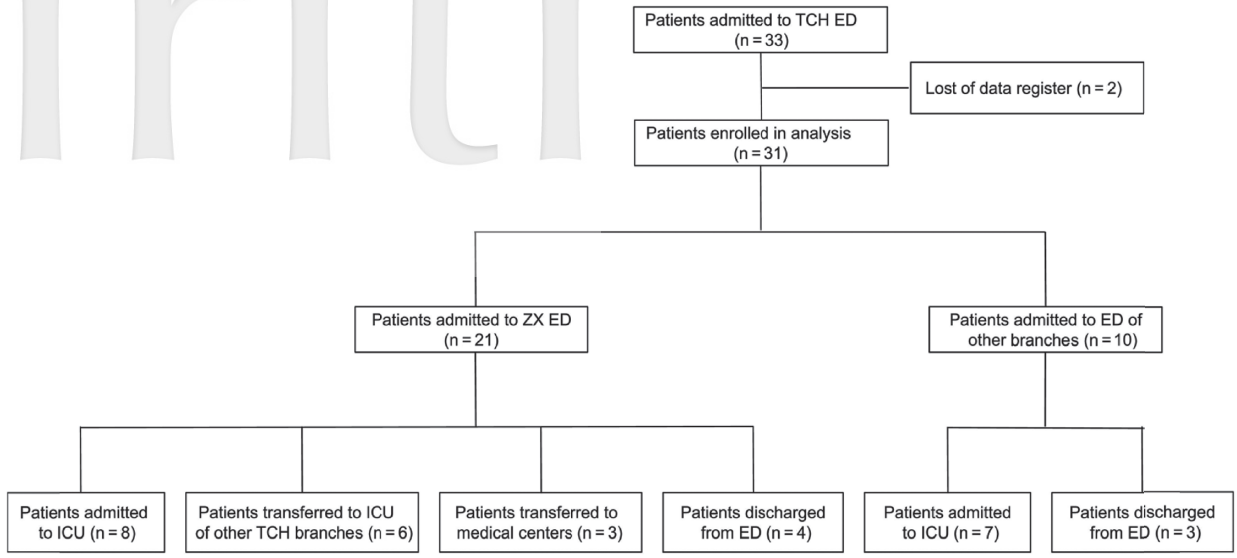

Fig. 4. Flowchart depicting patients' disposition.
ED: emergency department; ICU: intensive care unit; TCH:Taipei City Hospital; ZX: Zhong-Xing branch.

This study was approved by the hospital Institutional Review Board (approval No: TCHIRB-10802008-E) with informed consent obtained before the study.

Results

The Emergency Operation Center notified the EDs of the various branches of the TCH to prepare for the mass casualties within 30 minutes after the event without any further details. The geographic location of the incident and the Zhong-Xing branch are shown in Fig. 1. The ED of the Zhong-Xing branch dispatched a team with an emergency medical technician, an emergency physician, and a nurse practitioner to the scene. Further, the ED staffs received the first patient and encountered the subsequent mass casualties surge within one hour. Fortunately, the casualties were all invariably burn injury victims. The ED staff managed the casualties in a production line pattern: the emergency nurses triaged the patients; the emergency physicians evaluated the patients, gave orders, and organized the recruited physicians for specific tasks, such as re-triaging, administering pain killers, inserting the Foleys and monitoring the urine outputs, and manually monitoring patients to check if they showed any subjective or objective signs of respiratory distress; the recruited nurses dressed the burn wounds at the bedside; the radiologist placed the central lines for fluid resuscitation under sonographic guidance; the pharmacists obtained dressings and medication supplies from other branches and pharmacies in the neighborhood; and the social workers and administrative staff managed the mood of the families and patients and updated information. As plastic surgeons from other branches arrived at the ED of Zhong-Xing branch, they evaluated the patient for the necessity of emergency escharotomies and transferred some of the patients directly to the operating rooms (ORs) of other branches. The surgeons of general surgery, genitourinary, orthopedics, and neurosurgery all received the assignment to take care of patients in the ward or ICU, based on the requests of emergency physicians and under authorized permission from the chief of the TCH.

In total, 33 patients were admitted to TCH, but two of them were dropped out of analysis due to missing medical records. Among these patients, 21 were admitted to the ICU wards, seven were discharged from the ED, and three were later transferred to other hospitals according to the will of the patients and families (Fig. 4). The number of patients that arrived and the surge in ED related to time are illustrated in Fig. 2.

Overall, the mean age of the patients was 23.2 years. The average initial estimated TBSA with burn injury was 34.2%, and the average final TBSA with burn injury assessed in the ICU was 41.0%. There were only four patients who were intubated immediately due to severe mucosal injury or respiratory failure. Subsequently, three patients were intubated in

the OR due to anesthesia for emergency escharotomy. Only one patient was intubated due to respiratory complications one week after transfer to the ICU of another hospital. The average intubation rate during TCH stay was 22.6%. The average fluid for resuscitation was 4.1 mL/TBSA (%)/body weight (kg), and it was achieved by the Parkland's formula. The average initial urine output in the first 24 hours was 2.3 mL/body weight (kg). The initial laboratory data of patients invariably showed prominent leukocytosis (28,000 ± 1,060/μL), mild elevation of aspartate aminotransferase (54.7 ± 21.9 U/L), and a mild increase in creatine kinase (522.1 ± 628.5 U/L). To date, there has been no mortality among these 31 patients who were initially managed by TCH. Table 1 presents the detailed demographics and outcome of these patients. Table 2 compares the delayed intubation rate and mortality rate with the data from Chang Gung Memorial Hospital (CGMH) and American Burn Association (ABA).[4,5]

The key elements during the interview of the interviewees for efficient initial response were the multidisciplinary response team cooperated as a production line, using the clipboards for orders recordings, and the plastic surgeons ED-OR direct transferring (100, 83.33, 66.67%, respectively).

Discussions

The Formosa Fun Coast waterpark dust explosion incident resulted in 499 burn injuries and was one of the major events of mass casualties not only in Taiwan but in the world as well. The patient surge within hours and the critical imbalance of burn management resources challenged the EMS network in north Taiwan. According to the data of the ABA, the mortality of burn injury with 40–59.9% in United States was 30.5% (1,024 out of 3,354).[5] However, for the average burn injury of 44% TBSA in this incident, the mortality was only 2.4%.[6] This is truly a triumph of the local EMS network. TCH, a regional-scale hospital with limited capacity and burn management resources, resuscitated 33 burn patients within the first response period without any documented mortality and managed the patients until the definite burn care facilities could take over. Inadequate amount of personnel with specialized burn care training is frequently encountered during events with mass burn casualties, and the labor-intensive nature of management of burn injuries further complicates the management process.[7] Fortunately, the casualty patterns were similar in this event, and the goals of initial resuscitation were straight-forward: airway evaluation and management, intravenous route placement and adequate fluid resuscitation, pain control with morphine sulfate, wound care, monitoring the response of management of urine output, and disposition to proper facilities for further management. The multidisciplinary response team of TCH cooperated as a production line and managed the burn patients efficiently. During this incident, the emergency staff led the team and assigned specific tasks to the recruited members; the recruited members worked with a task-oriented approach and were grouped for only one specific task, such as setting the intravenous route, administering pain killers, inserting the Foleys and monitoring the urine outputs, monitoring respiratory conditions, and dressing the wounds. Such a flat team organization minimized the factors of inexperience and increased the efficiency of patient management, especially during the surge. The plastic surgeons recruited from other branches approached the patients directly, prepared the ORs of other branches for emergent escharotomy, and transferred the patients without delay, which further improved the standard of care of the burn injury patients.[8] Within six hours, the initial response team of TCH had managed the patient flow and restored the ED for emergency service (Fig. 2).

Since the number of patients (n = 12, 38.7%) with facial burn exceeded the available ventilator capacities, and the ICUs in the neighboring hospitals were all occupied after the incident, the emergency physician who was the incident commander in the ED decided to intubate the patient only in case of mucosal burn injury. After evaluating each patient, only one patient with cornea burn ulcer was intubated immediately in the ED of Zhong-Xing branch. Three patients in other branches were subsequently intubated in the ICU within 24 hours. Further, three patients were intubated selectively in the OR for escharotomy. The TCH received 31 patients with 38.7% facial burn and the overall intubation rate within 24 hours was 22.6%, which was lower than that of the CGMH, that received 49 patients with 35% facial burn and intubated 59% of the casualties.[9] It is general practice to intubate patients with airway burn or inhalation injury early to avoid the risk of edema and the loss of airway patency. The Advanced Trauma Life Support (ATLS), the Advanced Burn Life Support (ABLS), and other reports have suggested that prophylactic intubation of patients with inhalation injury or

Table 1. The basic demographics, initial condition, airway management, resuscitation management, laboratory results, and mortality of 33 patients[a]

Variable	Value (n = 31)
Basic demographics	
Sex (male), n (%)	18 (58.0)
Age (years)	23.2 ± 4.0
Initial conditions	
Initial TBSA%	34.2 ± 22.2
Final TBSA%	41.0 ± 28.3
BW (kg)	62.0 ± 15.2
Facial burn, n (%)	12 (38.7)
BT (°C)	36.3 ± 0.55
MAP (mmHg)	97.5 ± 16.2
HR (bpm)	111.7 ± 19.3
Shock index (HR/SBP)	0.88 ± 0.26
SpO_2%	98.9 ± 0.78
Airway management	
Immediate intubation, n (%)	4 (12.9)
Elective intubation for surgery, n (%)	3 (19.4)
Resuscitation management	
Use of vasopressors in ED, n (%)	1 (3.2)
Initial fluid in first 24 hours [mL/TBSA (%)/BW (kg)]	4.1 ± 0.8
Initial urine output in first 24 hours [mL/BW (kg)/h]	2.3 ± 1.6
Laboratory results (27 out of 33 patients had available data)	
Glucose (mg/dL)	140.2 ± 45.5
Creatine kinase (U/L)	522.1 ± 628.5
Aspartate aminotransferase (U/L)	54.7 ± 21.9
Blood urea nitrogen (mg/dL)	14.2 ± 3.4
Creatinine (mg/dL)	0.9 ± 0.3
Na (mEq/L)	136.5 ± 5.4
K (mEq/L)	4.0 ± 0.7
White blood cells (10^3/uL)	28.0 ± 10.6
Hemoglobin (g/dL)	16.5 ± 2.3
Platelets (10^3/uL)	271.8 ± 61.0
Neutrophils (%WBCs)	86.7 ± 4.5
International normalized ratio	1.1 ± 0.1
Mortality	0
Key elements for initial response (percentage of interviewee, n = 6)	
The multidisciplinary response team cooperated as a production line	100.00
The response team were provided clipboards for orders recordings	83.33
The plastic surgeons ED-OR direct transferring	66.67

BT: body temperature; BW: body weight; ED: emergency department; HR: heart rate; MAP: mean arterial pressure; OR: operating room; SBP: systolic blood pressure; SpO_2: peripheral capillary oxygen saturation; TBSA: total body surface area; WBCs: white blood cells.
[a]All values are presented as a number, percentage (%), or mean value ± SD.

Table 2. Comparison of airway complications and mortality of the Taipei City Hospital and the result of the Chang Gung Memorial Hospital, and the American Burn Association 2015 National Burn Repository of Data from 2005–2014[2,3]

Hospital	n	TBSA (%) of burn injury	Mortality (%)	Delayed intubation (%)
TCH	33	41.0 ± 28.3	0.0 (0/33)	3.0 (1/33)
Primary to CGMH	35	49.2 ± 19.3	5.7 (2/35)	14.3 (5/35)
Received from other hospital	11	52.1 ± 12.1	9.1 (1/11)	27.3 (3/11)
ABA	3,354	40.0–60.0	30.5 (1,024/3,354)	—

ABA: American Burn Association; CGMH: Chang Gung Memorial Hospital; TBSA: total body surface area; TCH: Taipei City Hospital.

airway burn may decrease mortality.[10] A study showed that 76% of patients with TBSA > 30% received intubation.[11] However, there were reports that argued the necessity of preventive intubation and claimed that around 40% of intubation was unnecessary.[12] The staff at TCH intubated the patients strictly based on evidence of mucosal injury under the situation of limited number of ventilators and ICUs, however, no patients received delayed emergent intubation due to airway edema. A possible explanation is that in this incident, the patients were alert, and the exposure time to flame was less than the usual burn injury; thus, the inhalation injury had reduced severity. The estimated exposure time was less than 20 minutes (from the explosion to the first patient that arrived at ED).[6] Hu et al. had examined the inhalation injury grade of patients in the same incident by bronchoscopy, and the result showed mild to moderate inhalation injury,[13] which may support this assumption. However, it was anticipated that patients may need further intubation due to the edema of the airway. Only one patient, who was initially managed in TCH, had received intubation one week after being transferred to another medical center, and it was due to a complication of respiratory tract infection and not related to the airway edema caused by inhalation injury.

The casualties were rushed into the ED for medical care without any identification profiles. However, a majority of the patients had a large area with burn injury over the chest and extremities, such that wearing triage necklaces or hand rings would be unsuitable. The response team were provided clipboards for orders and medication recordings to overcome the problem. Although, this may lead to misidentification, especially if the patients are ambulatory, fortunately, the casualties remained on their beds to avoid pain from the movement, and this reduced the risk of misidentification of patients. Further study involving the latest technology such as QR code and electronic sensor chip may solve these problems.[3]

The mass casualty code for recruiting all hospital staff was activated at the moment of patient surge; however, the phone text messages were not sent out due to the chaotic situation. Fortunately, most of the staff saw the breaking news of the national disaster and returned to the hospital voluntarily to provide sufficient medical capacity and facilitate patient care. A duplicated alarm system and verification pathway were crucial, and these were created after the incident.

In conclusion, airway complications, and mortality in patients who were initially managed at TCH, was comparable to those who were directly sent to the burn care units. A week after the incident, social media had raised a debate that dispatch of casualties to the regional hospitals, instead of burn care units, had led to a high mortality rate. Further, there was a dispute whether patients who suffered from major burns should have been transported directly to the burn centers instead of receiving initial resuscitation in the nearest regional hospitals. However, it was based on the unrealistic assumption that sufficient burn care units were available at the time of the incident. In reality, the number of casualties during the Formosa Fun Coast explosion exceeded the available burn ICU/ward beds in Northern Taiwan, and crowding the casualties in these rare facilities would have led to another disaster. Moreover, another study based on patients admitted to the CGMH, a trauma center, via primary or secondary transfer from other preliminary hospitals, did not show any difference in the amputation rate and mortality rate.[4] This study further supports the notion that immediate resuscitation provided the best chance for the survival of casualties even in hospitals without burn units provided they had recruited adequate response personnel.

Limitations

This study has some limitations. Since the

medical records on paper were either incomplete or had missing parts, and we had limited access to subsequent records after patients were transferred to a different hospital, not all laboratory statistics could be collected and analyzed. Additionally, as a retrospective, single-institution study, our patient group was small and may not be representative of the patients who were admitted to other non-burn-center hospitals. Third, the lack of data from other hospitals which participated in the initial response prevented us from conducting a statistical test for a detailed comparison.

Conflicts of Interest Statement

None.

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