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Adaptation Patterns to Cope with Burn Mass Casualty Incidents

Sheuwen Chuagn[1,2], David D Woods[3], and Sen-Kuang Hou[1]

[1]Taipei Medical University Hospital, Taipei, 11031,Taiwan
[2]Taipei Medical University, Taipei, 11031,Taiwan
[3]Ohio State University, Ohio, 43210, USA

ABSTRACT

Understanding and learning from hospitals' resilient behavior or adequate responses to beyond-surge capacity incidents to be better prepare staff for offering patients the appropriate, timely care is imperative. The study adopted the previous findings from the Formosa-Fun-Coast-Dust-Explosion studies as the base of data analysis. We synthesized the past discoveries and identified nine adaptation patterns. The results systematically organized how two initial receiving hospitals' responsive adaptations changed over time to cope with the difficulties in the emergency departments in the aftermath of the mass burn casualty incidents. The benefit of the pattern approach can increase the efficiency and effectiveness of the learning process.

Keywords: Resilience, Adaptive pattern, Mass burn casualty incident, Formosa fun coast dust explosion

INTRODUCTION

Large-scale burn disasters can produce casualties that threaten medical care systems. Hospitals need to provide essential emergency care during patient surge following a burn mass casualty incident. The Formosa Fun Coast Dust Explosion (FFCDE) occurred on June 27, 2015 in Taiwan, and caused 499 injuries. Most of these injuries constituted serious burns. Within 6 hours, 499 burn victims had been transported to 36 hospitals including 10 large medical centers, 23 regional hospitals, and 3 district hospitals across regions (Wang, et.al., 2017). These hospitals differed in their response capacity in terms of critical care bed numbers, burn care capability, accreditation level, and distance to the disaster scene. Despite the extreme patient surge and limited resources, the overall mortality rate was 3% (15 out of 499). This result was acknowledged by the international emergency medicine community.

Some initial receiving hospitals experienced severe difficulties due to insufficient surge capacity. According to the previous findings of the FFCDE studies (Chuang et al., 2019a, 2019b), the hospitals' emergency response plans did not fully support emergency medicine in the events. The hospitals relied on adaptive responses to deal with the patient surge to generate adequate emergency care resources accordingly. These adaptations were either irregular responses or ad hoc efforts to extend medical care for burn care in ED or wards, such as adjusted bure care treatment, abnormal material

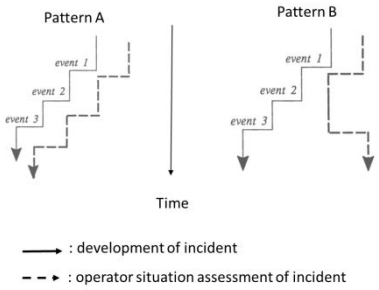

Figure 1: Concept of pattern (adopted from Woods 1988).

mobilization, and space reconfiguration. These adaptations differed from the planned or exercised emergency care activates, but were the keys to successfully dealing with the events.

Understanding and learning from hospitals' resilient behavior or effective responses to the incidents to be better prepare staff for offering patients the appropriate, timely care is imperative. Therefore, the study aimed to observe the initial receiving hospitals' responses in the emergency department (ED) period, and to identify adaptations patterns that played out over time and across various specific situations in the aftermath of a burn mass casualty incident. Ultimately, the identified patterns can cut through the variations in the surface responses to reveal underlying and regularities of emergency care services during mass casualty events for future efficient learning.

METHODS

This study is part of a larger project centered on the development of resilient disaster response strategies. It focused on analyzing the hospitals' responses to the situations they were challenged in ED period, starting when the hospital was first informed of the FFCDE and ending with the discharge or transfer of all FFCDE patients from EDs. It collected the interview data with clinicians and relevant hospital records from two initial receiving hospitals beyond their surge capacity. Data analysis of the two hospitals' responses involved chronological process-tracing analysis, synthesis, and compare and contrast analysis in developing responsive adaptation patterns. The contents of these analysis are described in more detail in individual publications about each hospital (Chuang et al., 2019a, 2019b).

The synthesis process of developing adaptation patterns based on softw-are engineering definition for patterns. Which patterns illustrate solutions to problems that can be applied, in a suitable context, many times but never end up with completely identical solutions (Gamma et.al., 1995). This definition of patterns represents three main elements of a pattern: the context, problem, solution paradigm. Besides, the study adopted Woods' concept chart describing the patterns' meaning with time changes (Fig. 1) (Woods, 1988).

Hence, the definition of adaptation patterns used in this study provides a format of describing context, time, response to presented problem, and cascaded issues.

RESULTS

Based on hospitals' characteristics, the detailed timelines of hospitals' overload situations, and descriptions for hospital's responses in separate publications, the study found three prominent shortages: lack of staff (burn professionals, clinicians, administration personnel); structure (ED space, beds), and stuff (burn medical materials, ambulance, stretchers). A variety of adaptations was synthesized into responsive adaptation patterns. Five types of adaptation patterns (P1 – P5) with alternative subtypes, i.e., P1a, P1b, due to the context changed over time. Overall, there are nine patterns found (Table 1 – 3). Each responsive adaptation coping with a specific shortage indicates the critical role which took the responsibility to proactively or reactively deal with the problem within a particular context. Besides, each pattern presented the cascaded issues triggered by its previous adaptations and was either controlled synchronically by proactive initiatives or reacted while facing the problem.

Table 1 demonstrates three patterns in two dimensions: level of burn care expertise and insufficient staff. Hospitals with different burn care expertise levels directed different emergency medical treatments that developed different cascading effects on shortage of structure and stuff. Such as "caused the gridlock of trauma room and other ED space," and "quick shortage of intubation devices and equipment." Besides, a typical adaptation pattern to cope with insufficient staff overtime was identified. Due to their low priorities, the pattern caused two cascaded problems that were not solved during the MCI period. They are "incomplete medical documentation" and "incomplete and imprecise mass casualties list in time."

Table 2 indicates three patterns to cope with the shortage of ED space, ICU-/burn beds. Patterns P3a and P3b are distinct due to distance to the disaster scene. Although EDs have an escalation policy of relocating existing patients to open acute space for victims, hospitals lacked the disaster information in time and uncertainty about the victims' arrival. They often adopted a stepwise relocation procedure under a contingency event. As a result, either generated cascading effect on ED space, i.e., the gridlock of trauma room and other ED space, or adjusted emergency medical treatments for victims, i.e., deferred coating ointment. A reorganization and re-ordering ED disorders in time is imperative to resume ED operation efficiency. In addition, a typical adaptation pattern to cope proactively with lack of ICU beds was identified (ICU bed-P4), and anticipation of a shortage of special burn care teams for the boarded burn patients enabled the mobilization of clinical staff in advance through the best use of hospital's convenience extensibility.

Table 3 shows three patterns (P5a, P5b, P5c) coping with stuff shortage. The patterns were distinguished by the stock level of burn care materials and the demand of burn patients. Coordinately bypassing standard procedures across roles, units, and external organizations to quickly fulfill demand were the typical responses though the demand for stuff was varied. Shortage of stuff could be recognized easier by the hospital with limited burn care materials than the hospitals with moderate inventory levels of burn care materials under the effect of uncertainty about victims' information. Rapidly reactive

Table 1. Responsive adaptation patterns –Interacting effect due to shortage of staff.

Pattern	Context	Shortage recognition	Responsive adaptations coping with presented shortage	Cascaded issues
Staff – P1a	No-burn expertise hospital located farther to the disaster scene	1. Anticipating an influx of burn patients would come and shortage of burn experts and clinicians. 2. Clinicians on duty had limited experience at burn care for the burn MCs.	• **VP** proactively initiated the alerting call to mobilize ED and surgical managers when she saw news report off-site before the victims came. • **ED OdP and OdHN** proactively activated ERP alarm after received EOC and VP's call before the first victim arrived. • **SD** led patient stabilization and mainly followed emergency burn care protocol, including coating every burn patient in full scale. • Reasonably without intubation for burn patients but closer monitoring them in ED	• *Quickly reaching shortage of burn ointment & others in ED* • Might *develop risks of deterioration for high-acuity patients*
Staff – P1b	Less-burn expertise hospital nearby the disaster scene	1. Victims with several high-acuity patients arrived unexpectedly fast 2. More patients needed intubation which demanded intubation experts	• **OdP and OdHN** activated ERP alarm after treating the first two sever burn patients. • **ED OdP** followed emergency burn care protocol and made necessary intubations and coated most not all victim with full scale burn dressing. • **ED OdP** urgently called for on-site physicians to assist intubation • **Senior managers** called for offsite physicians	• *Caused the gridlock of trauma room and other ED space* • Quick *shortage of intubation devices and equipment but not burn dressing* • *More intubated patients in ED waiting for ICU beds*
Staff – P2	Hospital with insufficient staff for burn care, registration, and documentation	1. Victims continuously arrived with uncertainty about how many burn patients would come, 2. Lack of clinicians and administration staff 3. *Duplicated or missed patient ID were confused by clinicians* 4. Anticipation *of shortage of special burn care team for the transferred patients in wards at next following days*	• **ED OdP** coordinately reconfigured the on-duty working team in ED before the first victim arrived. • Quick triage and organization of clinical teams changed over time as victims and staff arrived in the ED. • *Clinician* **managers** called for offsite staff. • **Senior managers** called EOC to stop sending • **ED nurse leader** or nurses assisted the triage for non-burn patients and registration. • Discharged relatively lower risk patients • Medical documentation was deferred • Simplified transfer procedures by oral handoff, plus limited documents provided afterword. • **ED team** initially followed the regular emergency protocol for triage and registration, till confusion of patient identification was discovered, then changed into MCI patient registration numbering system and reorganization of patient IDs • Deferred reporting the information of MCs to MOHW on line • Staff worked overtime to extend care from ED to wards. • **Senior managers** proactively organized CDTs for the following days' treatment.	• *Duplicated or missed patient ID were confused by clinicians* • *Incomplete* medical documentation • *Incomplete* and imprecise mass casualties list in time

ED OdP: Emergency department on-duty physician, OdHN: on-duty head nurse, SD: surgical director, VP: vice president of the hospital, PS: plastic surgeon, CDTs: change dressing teams, MCI: mass casualty incident.

Table 2. Responsive adaptation patterns – Interacting effect due to shortage of structure.

Pattern	Context	Shortage recognition	Responsive adaptations coping with presented shortage	Cascaded issues
ED space-P3a	Distant hospital continuously received burn patients with uncertainty	1. Anticipation of shortage of acute beds in ED before burn patient arrived. 2. Victims would continuously arrive	• ED OdP initially followed the regular emergency protocol to relocate patients in the acute area to open space for sever victims • ED OdP relocated non-burn patients except the acuity one to the nearby hospital lobby at the early beginning • Discharged non-burn low-acuity patients	• No space issue occurred
ED space-P3b	The closest hospital continuously received mass casualties with uncertainty	1. Anticipation of shortage of acute beds in ED before burn patient arrived. 2. Victims continuously arrived, exhaustion of acute beds in ED andovercrowding ED other spaces quickly *3. Approaching the gridlock of trauma room and other ED space*	• ED OdP initially followed the regular emergency protocol relocate non-burn patients in the acute area to open space for sever victims • Stepwise relocation of non-burn patients from one area to another area inside of ED and did not have space and access control. • **PS** suggested to stop coating burn ointment to open ED space and speed up boarding. • Minor injured were first treated in triage area outside of ED room, and meeting room, storage room, staff lounge, and shower room were opened up to allow low-acuity patients to flush their own burns • Discharged non-burn low-acuity patients • **A senior ED manager** returned and noticed the ED was overcrowded, and initiated rectification of ED disorder to gain efficiency in ED space.	• *Approaching the gridlock of trauma room and other ED space* • *Deferred coating ointment led the shortage of burn ointment later* • ED space was reconfigured and ED back to a controlled state
ICU beds – P4	Hospitals had limited ICU beds for high-acuity burn patients	1. Anticipation of shortage of ICU beds while saw the influx of severity level of burn patients 2. Not enough ICU beds (*Intubated patients in ED waiting for ICU beds)* *3. Might develop risks of sever deterioration for high-acuity patients*	• *Senior* **manager** proactively activated emergency transfer protocol in the ICU and general wards to mobilize ICU/ward beds • **ICU physicians and nurses** communicated with stable ICU patients' families to get their agreement for relocation • **LC** centrally controlled how many ICU beds were mobilized timely • **LC** transferred some likely serve burn patients to GWs, but before the transfer, **he or PS team** proactively mobilized the ward on-duty physicians to re-evaluate and further re-treat the transferred patients on arrival. • **VP** asked to call every hospital with available ICU beds for arranging quick hospital transfer.	• *Shortage of special burn care team for the transferred patients in wards at the next following days* • One acuity patient was found in need of intubation in the ICU

ED OdP: Emergency department on-duty physician, OdHN: on-duty head nurse, LC: local commander, VP: vice president of the hospital, PS: plastic surgeon, CDTs: change dressing teams, GWs: general wards

Table 3. Responsive adaptation patterns – Interacting effect due to shortage on stuff.

Pattern	Context	Shortage recognition	Responsive adaptations coping with presented shortage	Cascaded issues
Stuff – P5a	Hospitals had limited medical materials for burn patients	1. ED used up all burn care materials in ED stock 2. Anticipation of shortage of medical materials in hospital inventory 3. ***Quickly reaching shortage of burn ointment & others in ED***	• **OdHN** mobilized internal materials from hospital's inventory and coordinately bypassed standard inventory procedures & admission of control drug with inventory staff and clinicians. • **VP** proactively mobilized external materials from MOHW allied hospitals in the early overload stage. • **ICU nurse** returned to her ICU to "liberate" some packs of burn ointment while ran out burn dressing in ED. • **The allied hospitals** provided rapid supplies during the overload ED period.	• Burn materials except for medications, had no issues in wards.
Stuff – P5b	Hospitals had moderate level of medical materials for burn patients	1. ED used up all burn care materials in ED stock and then the hospital's inventory 2. ***Deferred coating ointment led the shortage of burn ointment later***	• **OdHN** mobilized internal materials from hospital's inventory and coordinately bypassed standard inventory procedures & admission of control drug with inventory staff and clinicians. • **A network hospital** nearby accordingly supplied burn care medical materials • **A young attending physician** anticipated the exhaustion of burn ointment after transferring patients, took the initiative to call a supplier and requested an urgent delivery of burn ointment.	• Burn materials except for medications, had no issues in wards
Stuff – P5c	Hospital received more victims than surge capacity and intubated more patients in ED	1. ***Quick shortage of intubation devices and equipment*** 2. Exhaustion of stretchers 3. Lack of ambulances and escort clinicians when ED started hospital transfer for the intubated patients	• **ED head nurse** borrowed tubes, ambu, and portable ventilator equipment by bypassing standard procedures • **Nurses** put patients with injured limbs in wheelchairs before finding stretchers • **ED head nurse** borrowed stretchers from 119 ambulances • **ED head nurse** coordinately worked with administration staff formal and informal mobilized ambulances. • **Senior attending doctors** volunteered to escort the transferred patients.	• Burn patients were safely cared in ED, ambulance, and wards

OdHN: on-duty head nurse

coordination between hospital staff was a familiar pattern to mitigate the impact of such challenges.

DISCUSSION AND CONCLUSION

This study utilizes the strengths of comparison and contrast analysis and synthesis between two non-burn center hospitals. Based on their unique capacities and limitations, the two hospitals were pushed into the position that needed to stand on their own to make varied adaptations or initiatives for tradeoff decisions. This paper has summarized and synthesized the emerging patterns of adaptive responses in EDs to a mass burn casualty incident followed the FFCDE. The findings have highlighted how hospitals adapted to the shortages of ED capacities by context, and the identified patterns can contribute to future learning for disaster planning and preparedness.

The adaptation patterns are the systematic knowledge of the variable responses with the context variation and timing affected these responses resulted from different hospitals that experienced the same disaster. According to Woods' situation assessment of incidents, actual incidents develop and evolve due to propagation of disturbances, additional faults, failure, or under-adaptation of human and machine elements to respond appropriately. The study's findings imply that situation changes against time played a critical role in evolving an incident and agents' responses [5]. The use of contextual adaptation patterns can assist hospitals' staff in dealing with changing events and consequences related to how they responded to them during a mass casualty incident. Variable responses of participants or units to the MCIs that lead to success in stabilizing patient life need to be supported. In contrast, those leading to risky cascading or undesired results need to be tempered.

The two hospitals conducted differently in several responses to deal with the difficulties. However, the successes of the adaptations included dynamically reconfiguring coordination and integration across roles and units and anticipation of potential bottlenecks. Moreover, timely anticipatory actions are essential to achieve effective positive results in individuals receiving hospitals. Therefore, when hospitals use the adaptation patterns should also recognize the coordination and communication efforts across units and individuals.

The identified patterns in the study provided a format to document the contents for disaster planning and preparedness, including describing context, time, response to the presented problem, and cascaded issues. The benefit of a pattern approach is that hospitals are able to take the idea from a pattern and adapt the principle of the responsive solution to solve the challenges or difficulties in front or near future, thus increasing the efficiency of the learning process.

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