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Strategies to Strengthen Hospital Response for Chemical, Biological, Radiological, and Nuclear Incident: A Multisite Study

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Abstract

Objectives: In responding to a Chemical, Biological, Radiological, and Nuclear explosive (CBRNe) disaster, clinical leaders have important decision-making responsibilities which include implementing hospital disaster protocols or incident command systems, managing staffing, and allocating resources. Despite emergency care clinical leaders' integral role, there is minimal literature regarding the strategies they may use during CBRNe disasters. The aim of this study was to explore emergency care clinical leaders' strategies related to managing patients following a CBRNe disaster.

Methods: Focus groups across 5 tertiary hospitals and 1 rural hospital in Queensland, Australia. Thirty-six hospital clinical leaders from the 6 study sites crucial to hospital disaster response participated in 6 focus groups undertaken between February and May 2021 that explored strategies and decision making to optimize patient care following a CBRNe disaster.

Results: Analysis revealed the use of rehearsals, adopting new models of care, enacting current surge management processes, and applying organization lessons were facilitating strategies. Barriers to management were identified, including resource constraints and sites operating over capacity.

Conclusions: Enhanced education and training of clinical leaders, flexible models of care, and existing established processes and tested frameworks could strengthen a hospital's response when managing patients following a CBRNe disaster.

The key goal of health and medical responses following a disaster is to do the greatest good for the greatest number of people.[1] In an acute tertiary hospital, this disaster response is optimized if emergency and critical care services, which are characterized as care provided by the emergency department (ED), intensive care unit (ICU), and operating theaters (OT), can provide an adequate surge response.[2–5] Surge capacity within a hospital setting involves the ability to manage a sudden influx of patients and provide acute care to both critical and non-critical patients simultaneously during a mass-casualty, disaster situation.[4,6,7] The role of clinical leaders is an integral part of this, as they have strategic and decision-making responsibilities such as implementing hospital disaster protocols or incident command systems, managing staffing, and allocating resources. Despite their integral role, there is minimal discussion in the literature regarding strategies used by clinical leaders during chemical, biological, radiological, nuclear, and/or subsequent explosive (CBRNe) disasters.

A disaster can be defined as "a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its resources,"[8(p9)] and in simplistic terms can be categorized as conventional (e.g., bushfires, floods, cyclones) or nonconventional (e.g., CBRNe, deliberate acts of harm).[9,10] A CBRNe incident is defined as an incident that involves the threatened or deliberate release of a chemical, biological, or radiological agent or activation of a nuclear device, which is intended to cause harm to people, animals/plants, property, or the environment.[11] The intent to harm may relate to political, ideological, criminal, or revenge motivations.

CBRNe disasters are distinctly different to conventional disasters and present unique challenges for hospitals and staff, typically occurring without notice.[12] Recent examples of CBRNe disasters include the Port of Beirut explosion (chemical disaster) in 2020 where poorly stored ammonia nitrate exploded causing an enormous impact on the community and health system.[13]

The COVID-19 pandemic (biological disaster) provides many examples of the impact of a novel virus on health systems across the globe.[14–16] Furthermore, current conflicts in Europe[17] and the middle East place a spotlight on the potential for CBRNe warfare. These examples highlight the importance of hospital readiness for CBRNe disasters, a vital component of which is to generate a deeper understanding of the role and strategic decisions of clinical leaders.

Often there is a level of uncertainty associated with a CBRNe disaster; for instance, a sudden influx of many patients to hospital in a short period of time, all experiencing similar symptoms, but from an unknown cause.[18,19] The origin of CBRNe-related symptoms can be difficult due to their similarity with other diseases, such as exotic toxins, or poisons or severe radiation poisoning causing nausea and vomiting, making CBRNe exposure difficult to diagnose.[20] This can lead to delays in appropriate treatment.[21,22] CBRNe disasters may be frightening to the general population and public uncertainty can result in hospitals becoming inundated with "worried well," people seeking treatment out of fear.[23,24] Additional challenges can occur if emergency health care personnel are affected by secondary contamination[21,25], such as from contact with contaminated clothing or off gassing from patients. This emphasizes the need for the removal of patient clothing and decontamination of patients before entering the emergency care setting[21,26] and access to appropriate personal protective equipment (PPE) for frontline staff.[27]

Many Australian hospitals have demonstrated their ability to surge following conventional disasters.[28] However, it remains unclear if Australian hospitals can provide a surge response and care for the unique needs of patients following a CBRNe disaster. Globally, researchers have identified weaknesses in hospitals' ability to respond to CBRNe disasters.[23,29–33] Due to their vital role in the initial response to disasters, we aim to explore hospital clinical leaders' strategies for managing patients following a CBRNe disaster in the Australian context.

Methods

Design

A qualitative design was employed using moderated focus groups to collect data from February 2021 until May 2021. This study formed part of a larger multi-method sequential study to describe how prepared emergency care services are in their response to a CBRNe disaster.[9] The study is reported in accordance with the consolidated criteria for reporting qualitative research (COREQ) checklist[34] for interviews and focus groups.

Setting

This research was set in the state of Queensland, Australia. Queensland covers an area of 1 727 000 square kilometers and has the third-largest population of any Australian state or territory with 5.18 million people.[35] Queensland is the most conventional disaster-prone State or Territory in Australia with perennial floods, cyclones, and fires.[36] However, CBRNe events that result in multiple casualties are seldom seen in Queensland. The Queensland Health Disasters and Emergency Incidents Plan and Sub-Plans outline the roles and responsibilities of Queensland Health in a disaster or emergency incident, including being lead agency for multiple hazards. Each Queensland Hospital and Health Services has its own governance structures and disaster response processes.[37]

Population

The population for this study were clinical leaders including hospital disaster managers, emergency department medical and nursing managers, intensive care unit medical and nurse managers, anesthetic and perioperative clinical leads, trauma service leaders, and hospital educators.

Sample

Six hospitals were purposively approached to participate' due to their geographical or strategic location as outlined within the Queensland State Disaster Management Plan[37] relating to potential CBRNe events. There were 5 tertiary referral hospitals and 1 rural hospital. The tertiary sites were selected as they are pivotal to state-led disaster responses and contain specialist emergency care-related services required to treat adult and/or pediatric patients in Queensland. The rural hospital is located near several major facilities of strategic significance for Queensland and provides surge capacity to treat patients if a disaster occurred at the nearby military base, airport, coal mine, or power station. Within each of the 6 hospitals, an identified research lead was purposively recruited from the above-mentioned population. The hospital-based research leads contacted potential participants via telephone or e-mail. Potential participants were provided with an information sheet containing the aims of the project, the project method, and potential time commitment. If participants expressed interest, a further email was sent that included the participant information and consent form.

Data Collection

Six focus group sessions were conducted and digitally recorded and transcribed verbatim. The focus groups were facilitated by 2 or 3 members of the research team (2 were male and 1 female) who were experienced emergency disaster clinicians (BM, MB, SW); with support from an experienced PhD-prepared academic and qualitative researcher (JR). During the focus groups, 2 distinct CBRNe disaster scenarios were presented to all participants to stimulate discussion (supplementary item 1). These scenarios were developed and contextualized by the research team and were informed by the literature.[38] During the focus groups, the researchers provided direction (Table 1), and participants were prompted to verbalize the strategies they would use to problem-solve using a think-aloud methodology[39] to understand how they would achieve optimum patient care with available resources.[40]

Field notes were taken contemporaneously during each focus group and key themes that arose were written on a white board in the room using a mind-map diagram. At the completion of each focus group, participants were asked to check the mapped concepts for accuracy and completeness. Required changes were made. Participant demographic and background data were collected, including age, current role, qualifications, years working in the profession, years working at current hospital, previous experience of working during a disaster, and completion of formal disaster education or training.

Data Analysis

Content analysis of the transcripts and field notes was conducted using the analytical framework described by Miles, Huberman, and Saldana.[41] The approach initially involved 2 researchers (BM, JR): (1) assigning codes to field notes and interview transcripts using a

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Table 1. Focus group questions

- *What are your first priorities in this CBRNe scenario?*
- *What strategies do you employ as a clinical leader(s) to facilitate the early discharge of patients?*
- *What unique challenges exist at your hospital that hinders your ability to create surge capacity?*
- *How do you establish additional patient holding areas?*
- *What strategies have you applied to surge following a natural disaster? How would these differ/be the same for a CBRNe disaster? If different, why?*
- *Is a partnership arrangement in place with local health agencies, e.g., QAS, Red Cross to create emergency treatment capacity outside of the hospital?*
- *How are patients tracked in the hospital during disasters? If this is automated are staff confident to use this during a disaster?*
- *How do you link information and disseminate info to key players on the floor, and planners during a mass casualty event? How do you know this is effective?*
- *How do you ensure adequate qualified staff are available following a CBRNe disaster?*
- *What CBRNe education and training is available to staff in your hospital?*
- *What specific training do you feel staff need to adequately manage patient care following a CBRNe disaster?*
- *What non-medical issues impact on the delivery of care following a CBRNe disaster?*
- *What types of policies, clinical protocols or standing orders exist to guide care following a CBRNe disaster?*
- *What education and training have you undertaken in disaster management relating to CBRNe (e.g., how are staff trained to enact decontamination)?*
- *How do you use feedback from disaster exercises to improve practices in your area?*
- *How do you look after your staff during/following a disaster in the hospital?*

cross-case causal network analysis method; (2) codes were allocated to variables estimated to be the most influential, and for each case the stream of variables led to determining themes and categories; (3) streams that were similar across cases, or that differed from other streams were extracted; and (4) themes and subthemes were integrated into higher level connections through seeking plausibility, clustering, noting patterns, and making metaphors. Overarching meta-themes or categories were subsequently developed involving additional research team members (KH, MM, DW, JC) with consensus providing a comprehensive description and deeper understanding of hospital clinical leaders' strategies related to managing patients following a CBRNe disaster. Illustrative quotes were identified to enhance trustworthiness and credibility.[42,43]

Ethics

University and multi-site Human Research and Ethics Committee approval were gained (Ref No: 2020/562; HREC/2019/QGC/51920). Written informed consent was sought from participants before data collection commenced. Participants were advised that anonymity could not be guaranteed due to potential identification related to demographic details of their hospital. No names were recorded, and confidentiality was assured. Each hospital was assigned a number so as not to be identifiable by name.

Findings

Thirty-six clinical leaders from the 6 study sites participated in 6 focus groups, which each took approximately 80 minutes. Most participants were clinical nurses who had between 5 to 9 years' acute care experience; and were aged between 40-49 years (Table 2). Over half of the participants had no previous disaster training or experiences in enacting any disaster response; and those who had received training had mostly attended Emergo Train System[44] or Hospital Major Incident Medical Management and Support (HMIMMS/MIMMS) courses[45] (Table 3). The findings from the focus group transcripts and field notes were integrated and are reported here.

Table 2. Participant characteristics

Characteristic	*n* (%) *n* = 36
Age Group	
20–29	1 (2.8)
30–39	5 (13.9)
40–49	17 (47.2)
50–59	9 (25.0)
60 or older	4 (11.1)
Hospital	
A	8 (22.2)
B	6 (16.7)
C	6 (16.7)
D	6 (16.7)
E	5 (13.9)
F	5 (13.9)
Primary role	
Clinical nurse	11 (30.6)
Manager	7 (19.4)
Emergency physician	6 (16.7)
Trauma service clinician	6 (16.7)
Surgeon	2 (5.6)
Anaesthetist	1 (2.8)
Radiologist	1 (2.8)
Operation director	1 (2.8)
Intensivist	1 (2.8)
Years in current role	
Under 5	8 (22.2)
5 – 9	13 (36.1)
10 – 14	5 (13.9)
15 or Greater	10 (27.8)

The analysis uncovered 2 contrasting categories: (1) Facilitating approaches, and (2) Barriers to management (Figure 1). Most clinical leaders felt that within their hospital they could effectively enact strategies and manage patients following a CBRNe disaster; however, barriers were identified that potentially limited their response. The first category contained 4 themes that revealed strategies clinical leaders used to effectively manage patients following a CBRNe disaster, while the second category contained 2 themes that could hinder a hospital's capacity and capability to provide a surge response.

Facilitating Approaches

Most clinical leaders believed their hospital could effectively enact strategies and manage patients following a CBRNe disaster. Four of the themes that emerged from within the Facilitating Approaches category reflected strategies clinical leaders perceived would

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Table 3. Participant disaster experience

	n (%) *n* = 36
Previous disaster training	
Yes	16 (44.4)
Type of disaster training†	
HMIMMS	6
MIMMS	5
Emergo train system	5
AUSMAT	3
Other	3
Previous disaster response	
Yes	11 (30.6)
Type of disaster response‡	
Bus crash	2
Floods	2
Cyclone	2
Bombing	2
Earthquake	2
Tsunami	2
Other mass casualty incident	1
Hospital evacuation	1
Structural fire	1
Train disaster	1
COVID–19 IMST	1

†Some participants completed multiple training and/or education programs.
‡Some participants responded to multiple disasters.
HMIMMS: Hospital Major Incident Medical Management and Support; MIMMS: Major Incident Medical Management and Support; AUSMAT: Australian Medical Assistance Team Training; IMST: Incident Management Support Team.

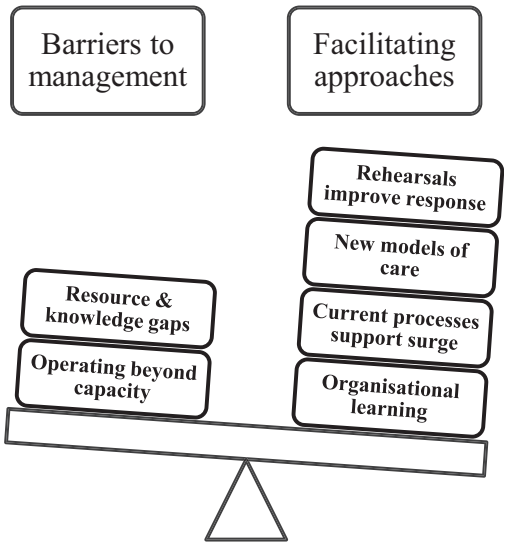

Figure 1. Categories and themes regarding CBRNe disaster management from hospital clinical leaders.

optimize staff, resources, and patient care and included: rehearsals improve response; new models of care; current processes support surge; and organizational learning.

Rehearsals Improve Response

Being involved in practice sessions such as tabletop exercises for major mass gathering events (i.e., international sports events or political gatherings) was considered beneficial as it supported collaboration and enhanced communication between specialist teams within the hospital, and with external agencies who are vital to a CBRNe response. For instance, one clinical leader from a trauma service gave an example of a successful exercise:

"When we had G20 here, we did disaster exercises at the hospital because of the participants, and we did a joint transfer of a person [Ebola patient] with RSQ [Retrieval Services Queensland] and rehearsed decontamination." (Hospital Site 3)

Participation in disaster training such as hospital wide real-time walk-through simulations, enabled clinical leaders to identify pragmatic approaches to optimize the treatment of patients following a disaster event, which could be applied to CBRNe patients. For example, a senior triage nurse said:

"…actually, one of the best learning we've had from disaster training for triage is giving people a word [color] … because no one can remember 6-digit numbers. For the Commonwealth Games if we have a bus load of athletes roll over you've got 30 20-year-olds with multi trauma.…our disaster packs come with pre-labelled blood tubes and spare stickers so that we can then label everything, and those tubes are all linked to a colour." (Hospital Site 1)

Cognitive aids, checklists and on demand disaster resources were generated by clinical leaders as a direct result of disaster simulated activities, which addressed gaps in the hospital's processes to surge and improve care decisions for any potential CBRNe patient. For example, a clinical leader from the ED described novel aids they had developed in their unit:

"…folders associated with every role and Code Brown [external emergency], and specifically for decontamination. We've got lots of visual resources; a dry decontamination box in all the Orange zone [isolation] rooms and they've got laminated cards with how to cut the clothes off.… or this is how you do dry decontamination." (Hospital site 5)

Similarly, in a large tertiary referral hospital, clinical leaders working in the peri-operative setting developed an effective system to support staff and patient care:

"For an actual mass casualty [for staff] coming to theatre, people [staff] that have been called in as extras get given a show bag… a lanyard tag and it tells them where to go and stand and what [phone] number they'll be called on. This is the equipment available. These are the timings. It's been probably one of our biggest lessons [Commonwealth Games and COVID] is that it's not about having everyone try and know a complicated plan." (Hospital Site 1)

New Models of Care

Clinical leaders were open to adopting new models of care delivery to effectively manage patients following a CBRNe disaster. For example, an ICU clinical leader stated:

"ICUs [staff] model change - we have the one-on-one [registered nurses to patient ratio] currently. We could change our model of care to have other people coming in and working with these ventilated patients… trained ventilator nurses would be looking after 1 or 2 [ICU patients]." (Hospital Site 2)

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Furthermore, ICU clinical leaders highlighted that they would alter the way they delivered care including shifting existing standards to optimize critical medical resources/consumables:

"We normally change things at certain intervals. We would stop changing wet circuits every 7 [days], we would just use what we've got, a bit like the PPE [personal protective equipment]. We conserve as much as we could until you resupplied it." (Hospital Site 4)

In addition to rationalizing staff and consumables, clinical leaders indicated that they would alter the way care was delivered to optimize bed spaces following a CBRNe disaster. For instance, it was highlighted by a participant that within their tertiary hospital,

"Each theatre and anesthetic bay is potentially an ICU surge [facility]." (Hospital Site 3)

Other leaders from the ED considered that innovative places to initiate patient care could be utilized:

"The idea of the ambulance bay becoming an [patient care] area, if you're really worried about bringing it through the hospital, if it's that spreadable, contagious, then you'd probably want to keep people out as long as you can so you can clear out people." (Hospital Site 4)

Current Processes Support Surge

Clinical leaders emphasized that in the event of a CBRNe disaster, predefined trauma/disaster plans, policies, and processes would be enacted to facilitate accessing additional staff and resources and optimize patient flow. For instance, at all sites a clinical leader referred to a Code Brown being the trigger to plan, prepare, and respond to a CBRNe incident because it would provide them with additional resources, specialist advice, and increased bed capacity. For example, one nurse manager commented:

"CBR events are automatically Code Brown events… clearing the department… make those things happen, wards would be motivated to pull patients from us [ED]." (Hospital Site 3)

Similarly, a peri-operative nurse manager stated:

"As soon as it's declared a Code Brown, from the surgical and perioperative setup, there's a whole – another tier of automation, that there's a bunch of people who will go and open boxes and put on vests. And theatres are held [pause any planned elective cases]. The recovery area is notified, and there's a team leader there who can decant patients from there - an anesthetic and a surgical commander will go to the emergency department." (Hospital Site 1)

Procedures existed for the specific management of burns, and a surgeon highlighted how this would assist their hospital in managing the unique needs of burns patients, which may present following a CBRNe incident, stating:

"There is a Queensland Burns Centre – state-wide burns plan – which extends right up to the northern border of New South Wales going up to Lismore. Patient movement is so coordinated in Queensland that the emergency management centre at Kedron would be involved straight away. So RSQ [Retrieval Services QLD] and QAS [Queensland Ambulance Service] is sitting next to each other directing those assets." (Hospital Site 1)

Furthermore, nurses working in the ED of a large tertiary hospital described pre-defined processes and resources that could optimize care for a large influx of patients, stating:

"…we've got well-rehearsed processes - have 300 Code Brown charts were made with pre-allocated UR numbers– the program has declared every patient that comes in, gets a disaster chart, and they have everything we could think of that you might need to do." (Hospital Site 5)

Organizational Learning

Analysis of the focus group data revealed that almost half of the clinician leaders had previous lived experience of managing patients following a mass casualty disaster, similar to the CBRNe scenarios provided. These experiences were viewed as being crucial in refining their understanding of how to enact CBRNe triage involving a large numbers of patients; one ED physician stated:

"I have been in one of those situations so that was in a Hospital [in New Zealand] and there was a school where there was a relieving teacher and they were mixing chemicals -and they mixed the chemicals and the relieving teacher turns the fan on, the exhaust, however it was winter, so it circulated around the whole school and we had 230 kids turn up in the ED. They didn't even tell us they were coming; they just all piled them into buses and brought them. - 5 got admitted but we still had to go through the 230 to get to those5. Lots of lessons learned." (Hospital Site 2)

Similarly, another emergency manager highlighted key learning that occurred when their unit was activated in 2020 following an explosion at a Coal Mine that involved 6 critically injured miners:

"…we can push patients out to every single ward, whether or not a bed is ready -effectively clear 20 – 20, 25 patients or so we've proven that we can do it, with the [X town] explosion." (Hospital Site 3)

Other clinical leaders described how the current pandemic had afforded them with key experiences in optimizing patient flow, which could be applied to the management of patients following a CBRNe disaster; one pediatric clinical specialist stated:

"COVID has been quite useful because we've actually practiced how we get people into ED, how we bypass ED with transferred patients from outside coming to PICU [Paediatric ICU]. You know closing off corridors and to using lift – dedicated lifts." (Hospital Site 5)

Intra-agency collaborations and partnerships had provided some clinical leaders with unique knowledge and skills, which they were able to apply to surge events within their hospital. For example, one ICU educator stated:

"…have a few experiences with the NCCTRC [National Critical Care Trauma and Response Centre] - led to a lot of processes being developed, particularly with some of the Code Brown disaster systems-it stopped it from being very insular and space-specific to now thinking out more broadly - so when COVID came around it was a very natural and organic process to have further discussions on other areas that we could potentially safely take over and supply." (Hospital Site 2)

Barriers to Management

Two themes emerged within Barriers to Management and included "resource and knowledge gaps;" and "operating beyond capacity." These themes reflected the perceptions of clinical leaders that existing processes, systems, staff expertise, and resources could hinder their ability to provide a surge response and effectively manage patients following a CBRNe disaster.

Resource and Knowledge Gaps

Most clinical leaders highlighted significant limitations in their hospital's capacity and capability to manage a large scale CBRNe disaster that required isolation and decontamination. Crucially, the space, and resources required for protection and decontamination (for both the patient and clinical staff), were viewed as inadequate, and staff were not proficient in how to enact decontamination. For example, a clinical leader from the rural hospital related how limited their resources were:

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"… the only place we've got is a hose [garden]. It's the best decontamination we've got at the moment, and only recently put in 1shower for staff." (Hospital Site 6)

The issue of inadequate decontamination processes was not unique to the rural hospital; trauma leaders at a large tertiary hospital highlighted similar issues:

"We have a decontamination trailer, which at the moment is not geographically in a good position. It was moved with COVID because where it was set up outside the ED, we then made a ward there instead." (Hospital Site 1)

Adequate PPE needed to effectively enact large scale decontamination was viewed as an issue, with one emergency nurse leader stating:

"We do have HAZMAT [hazardous materials] suits which are in the storage room behind Resuscitation room 3. However, we don't have multiple –only got 5 and not entirely sure how many nurses would know how to put on their suits. Also, there's an issue with the decontamination truck [operated by Queensland Fire Service] it comes from Brisbane – takes over an hour; it may not get here before the patients." (Hospital Site 1)

The inability to appropriately isolate patients within several sites was highlighted, with a peri-operative nurse stating:

"We've only got 1 COVID theatre, which is the only negative pressure theatre in the whole hospital." (Hospital Site 5)

Operating Beyond Capacity

Across all study sites, a dominant theme that emerged was the daily struggle to manage the existing clinical load; thus, surging to provide an enhanced response following a CBRNe disaster event was viewed as a challenge. Sourcing sufficiently qualified staff, or proactively training staff in key CBRNe patient care practices while managing their current patient load would be problematic and emerged through the following statements:

"The fact that we have got 20 people on the [ambulance] ramp sort of 4 days a week for ED;" (Hospital 2)
"a lot of the everyday business would still have to continue, because we've got 53 aged care residents who are here." (Hospital Site 6)
"We're short staffed - -day-to-day. We have staffing issues." (Hospital Site 4)
"…I mean, they're still struggling at the front door now when we've got concierge services [personalized support for patients to aid in navigating hospital admission]." (Hospital Site 2)
"…we've got 14 theatres in the theatre complex and any given day during the week, they're all being used." (Hospital Site 5)

Further, this view of daily working to capacity impacted the ability of clinical leaders to provide focused CBRNe education and training for staff, and 1 nurse educator stated:

"we've had so much training at the moment that's mandatory, for aged care, and acute, that it's just nearly impossible to add anything on top of that. And we're not saying it's not important." (Hospital Site 6)

Within the larger tertiary hospitals, clinical leaders highlighted issues of inexperienced staff. For example, one emergency director stated:

"…medical staff – we really struggle in emergency in the sense that 80% of our staff are only here for 10 weeks at a time and we just rotate, rotate, rotate. We get a set pool of registrars who come in for – do a year here and then go off and do pediatrics and then they go up and do ICU." (Hospital Site 1)

Discussion

CBRNe incidents have the potential to critically threaten the health of individuals and the community, as well as to seriously disrupt normal community and health service functioning. The initial decisions on how best to respond following a CBRNe incident are devolved to the local level, which, in Australia, is reinforced in national and state-based disaster policies. Therefore, clinical leaders within hospitals make important first response decisions.[5] As such, this cohort of clinicians were the focus of this study which was strengthened by the first-hand knowledge and expertise of the participants who are charged with decision-making around managing disasters.

Importance should be placed on preparing clinical leaders through relevant and adequate CBRNe focused education and training. Our findings suggest that most clinical leaders believed their hospital could effectively enact strategies and manage patients following a CBRNe disaster. However, this could be strengthened with CBRNe-specific training such as real-time simulations or tabletop exercises. For instance, clinical leaders in our study revealed that simulated CBRNe exercises and COVID disaster training fostered efficient collaboration between hospital sub-units and external agencies (e.g., retrieval services, police, fire/rescue), led to improvements in triage processes, and deepened the clinical leaders understanding of patient isolation and decontamination. Other researchers have identified that interoperability and integration is a key problem for governments' health care providers under crisis or disaster conditions;[46] however, disaster training and exercises are critical tools to improve collaboration among different responders with varying backgrounds, cultures, and operational processes.[22,47,48] While some clinical leaders in our study had undertaken formal disaster training, such as the Emergo train system or HMIMMS, participants highlighted the value of real walk-through disaster simulations and exercises, as they provide an authentic framework to improve decision making and optimize hospitals' responses to major CBRNe incidents, a finding consistent with other research.[49–51] Interestingly, the financial and time limitations of full-scale disaster exercises have been identified as a major barrier to frontline health professional training.[52] A safety culture and effective leadership are crucial to ensuring CBRNe disaster-specific training and education is enacted within hospitals and not relegated to "just in time" training. The barriers to teaching and learning in busy clinical settings have been well reported in the literature.[53–55] However, several approaches, such as Teaching on the run,[56] use of bedside rounds,[57] and institutional "protected time" seek to overcome such barriers. Medical and nurse education regarding the realities of disasters should commence at an undergraduate level,[58,59] which can then be built upon in the acute hospital setting to include site specific training. Teaching on CBRNe disasters should also integrate psycho-social self-care and support options that are considerate of before, during, and after a disaster.[60] This is paramount to retain clinicians and learn from people with lived experience.

To strengthen health systems for CBRNe events, there should be flexible models of care. To enhance the effectiveness of a hospital response, new yet untested models of care and rethinking how to enact medical consumable resupply may be required. This is especially so in regional settings where noted impacts on resources included staffing, difficulty obtaining PPE stocks and medication, and community response.[61] In this study, clinical leaders were clear that their focus during a CBRNe disaster event was to do the greatest good for the greatest number of patients, leading them to be open to adopting unfamiliar staffing models or endorsing pragmatic approaches to optimize the use of medical resources. For instance, clinical leaders in our study stated they could alter the nurse-to-patient ratios in ICU (typically 1:1 in Australia) to overcome potential staff shortages. Others have highlighted that limited

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research exists to inform how ICUs should prepare for a CBRNe disaster;[62] however, a focus on involving the entire interprofessional team and broad stakeholder input from other services within the hospital has been recommended.[63] Beyond clinical leaders, other clinicians may have alternative perspectives in CBRN preparedness.[63,64] Furthermore, those from outside the health domain may have insights into CBRN preparedness, such as those who understand health infrastructure and key vulnerabilities of hospitals.[65] The use of disaster medical caches for local or international deployment after a major incident has been reported[66] as a pragmatic strategy to maintain and sustain a local or regional stockpile of medical supplies. Noting the geographically-disparate location of the hospital sites and challenges in accessing adequate PPE (e.g., HAZMAT suits) reported by clinical leaders in our study, a pragmatic approach could be to develop regional CBRNe-specific caches (e.g., stockpiles of CBRNe specific medications, supplies, and equipment for mass casualty incidents); the Centres for Disease Control and Prevention (CDC) has well-established protocols and recommendations to inform the local use of regional CBRNe-specific stockpiles.

To strengthen health systems for CBRNe events, there should be processes that exist within established and tested frameworks. Health services and facilities routinely use international or nationally recognized response color codes for both internal and external emergencies.[67, 68] In Australia, a Code Brown is a nationally recognized hospital emergency alert usually reserved for transport accidents, chemical spills, natural disasters, or mass casualty events.[69] It aims to ease the burden on health services and make the best use of hospital resources by streamlining emergency management systems when there is an influx of patients over a short period of time. This was confirmed in our study when clinical leaders highlighted that a key strategy they would employ to support a surge response following a CBRNe disaster would be to activate a Code Brown; however, the clinical leaders revealed a barrier to enacting a surge response was inexperienced staff, highlighting the need for all staff to be oriented and familiar with a hospital's emergency response processes. Furthermore, integrating into protocols and policies the lessons learnt following a major incident has long been recognized as crucial for ensuring that hospitals are flexible and prepared to accept and manage patients at short notice,[70–72] and was a key strategy used by clinical leaders in our study.

Study Strengths and Limitations

A strength of this study was the sample of diverse clinician leaders who are responsible for disaster preparedness/response at their hospital. These clinical managers possess unique knowledge of the hospital's emergency and disaster capacity, which is not readily available or reported in the literature. Employing the "think-out loud" approach[73] in the focus groups was viewed as being effective because it afforded each participant the opportunity to verbally draw on their wide and varied experiences, elicit different decision-making, and highlight specific clinical requirements, which may not have been captured in other data collection methods (e.g., survey). The use of scenarios stimulated valid reflections that mirrored participant's cognitive processes.[73] However, the current study is confined to 6 sites in 1 Australian state, which may reduce the transferability of findings to other jurisdictions and other contexts. The detailed description of the population and sample provided, along with the disaster scenarios explored, may help others in ascertaining the applicability of our findings to their setting and approach to CBRNe management.

Conclusion

The survivability of casualties exposed to a CBRNe event is dependent on the decision-making of hospital clinical leaders and their ability to provide surge capacity, as well as the isolation and decontamination capabilities at the hospital, and was the focus of this study. Understanding the effectiveness of the strategies and rationales used by clinical leaders that enhance surge capacity during a disaster is vital for optimizing how hospitals respond and care for patients following a disaster and may inform future education and training. To strengthen the health service for CBRNe events, there should be adequate education and training of clinical leaders, models of care that are flexible, and processes that exist within established and tested frameworks. With the increasing occurrence and reporting of CBRNe events, future research is warranted to develop predictive models of disaster response efficacy.

Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/dmp.2024.151.

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References

1. **Cocco A**, **Patel B**, **Janesn M**, et al. Expression of ethical principles in Australia's disaster plans. *Emerg Med Australas*. 2022(6):989–994.
2. **Sundnes KO**. Information. *Scand J Public Health*. 2014;**42**(Suppl 14): 135–147.
3. **Park S**, **Jeong J**, **Song K**, et al. Surge capacity and mass casualty incidents preparedness of emergency departments in a metropolitan city: a regional survey study. *J Korean Med Sci*. 2021;36.
4. **Hasan MK**, **Nasrullah SM**, **Quattrocchi A**, et al. Hospital surge capacity preparedness in disasters and emergencies: protocol for a systematic review. *Int J Environ Res Public Health*. 2022;**19**(20):13437.
5. **Einav S**, **Hick JL**, **Hanfling D**, et al. Surge capacity logistics. *Chest*. 2014;**146** (4):e17S–e43S.
6. **Kelen GD**, **Kraus CK**, **McCarthy ML**, et al. Inpatient disposition classification for the creation of hospital surge capacity: a multiphase study. *Lancet*. 2006;**368**:1984–1990.
7. **Traub M**, **Bradt DA**, **Joseph AP**. The Surge Capacity for People in Emergencies (SCOPE) study in Australasian hospitals. *Med J Austral*. 2007;**186**:394–398.
8. **United Nations International Strategy for Disaster Reduction**. 2009 *UNISDR Terminology on Disaster Risk Reduction*. Geneva, Switzerland:

United Nations International Strategy for Disaster Reduction (UNISDR); 2009.
9. **Mackie B**, **Weber S**, **Mitchell M**, et al. Chemical, biological, radiological, or nuclear response in Queensland Emergency Services: a multisite study. *Health Security*. 2022;**20**(3):222–229.
10. **Tin D**, **Granholm F**, **Hart A**, et al. Terrorism-related chemical, biological, radiation, and nuclear attacks: a historical global comparison influencing the emergence of counter-terrorism medicine. *Prehosp Disaster Med*. 2021; **36**(4):399–402.
11. **Australian Government**. Domestic Health Response Plan for Chemical, Biological, Radiological or Nuclear Incidents of National Significance. In: *Department of Health*, editor. Canberra: Australian Government; 2018: 69.
12. **Nadworny D**, **Davis K**, **Miers C**, et al. Boston strong - one hospital's response to the 2013 Boston Marathon Bombings. *J Emerg Nurs*. 2014;**40** (5):418–427.
13. **Helou M**, **El-Hussein M**, **Kurtulus A**, et al. Beirut Explosion: the largest non-nuclear blast in history. *Disaster Med Public Health Prep*. 2022;**16**(5): 2200–2201.
14. **Tessema GA**, **Kinfu Y**, **Dachew BA**, et al. The COVID-19 pandemic and healthcare systems in Africa: a scoping review of preparedness, impact and response. *BMJ Glob Health*. 2021;**6**(12):e007179.
15. **Kendzerska T**, **Zhu DT**, **Gershon AS**, et al. The effects of the health system response to the COVID-19 pandemic on chronic disease management: a narrative review. *Risk Manag Healthc Policy*. 2021;**14**:575–584.
16. **Haldane V**, **Jung A-S**, **De Foo C**, et al. Strengthening the basics: public health responses to prevent the next pandemic. *BMJ (Clinical research ed)*. 2021;**375**:1.
17. **Erickson TB**, **Harvin D**, **Schmid A**, et al. Evaluation of Chemical, Biological, Radiological, Nuclear, Explosives (CBRNE) Knowledge Change and Skills Confidence Among Frontline-Line Providers During the Russia-Ukraine War. *Disaster Med Public Health Prep*. 2023;17.e387.
18. **Cummings C**, **Monti J**, **Kobayashi L**, et al. Ghost attack: the East Providence Carbon Monoxide Mass Casualty Incident. *R I Med J (*2013*)*. 2018; **101**(1):26–27.
19. **Nakayama JY**, **Surasi K**, **Owen LR**, et al. Assessment of chemical exposures investigation after fire at an industrial chemical facility in Winnebago County, Illinois. *J Environ Health*. 2023;**85**(7):8–15.
20. **McFee RB**, **Leikin JB**. Death by polonium-210: lessons learned from the murder of former Soviet spy Alexander Litvinenko. *Semin Diagn Pathol*. 2009;**26**(1):61–67.
21. **Rispens JR**, **Jones SA**, **Clemmons NS**, et al. Anhydrous ammonia chemical release — Lake County, Illinois, April 2019. *Morb Mortal Wkly Rep*. 2020; **69**(4):109–113.
22. **Christensen BE**, **Duncan MA**, **King SC**, et al. Challenges during a chlorine gas emergency response. *Disaster Med Public Health Prep*. 2016;**10**(4):553–556.
23. **Mohammadi SB**, **Amirheidari B**, **Dehesh T**, et al. Identification and analysis of parameters and global experiences of hospital preparedness against chemical, biological, radiological and nuclear disasters: a scoping review. *J Clin Res Paramed Sci*. 2022;**11**(1):e123626.
24. **Culley JM**, **Richter J**, **Donevant S**, et al. Validating signs and symptoms from an actual Mass casualty incident to characterize an Irritant Gas Syndrome Agent (IGSA) exposure: a first step in the development of a novel IGSA triage algorithm. *J Emerg Nurs*. 2017;**43**(4):333–338.
25. **Horton DK**, **Burgess P**, **Rossiter S**, et al. Secondary contamination of emergency department personnel from o-chlorobenzylidene malononitrile exposure, 2002. *Ann Emerg Med*. 2005;**45**(6):655–658.
26. **Oh JJ**, **Yong R**, **Ponampalam R**, et al. Mass casualty incident involving pepper spray exposure: impact on the emergency department and management of casualties. *Hong Kong J Emerg Med*. 2010;**17**(4):354–359.
27. **Razak S**, **Hignett S**, **Barnes J.** Emergency department response to chemical, biological, radiological, nuclear, and explosive events: a systematic review. *Prehosp Disaster Med*. 2018;**33**:543–549.
28. **Arklay TM**. Queensland's state disaster management group: an all agency response to an unprecedented natural disaster. *Austral J Emerg Manag*. 2012;**27**:9–19.
29. **Rosiello F**, **Manuel, M**, **Modini C**, **Russo, L**, **Marchetti, M**, **Zelinotti L**, **Vinci, A**, et al. Is rome ready for CBRNe attacks?. Inbuilding a strong CBRNe community 2016, pp. 51–51. *3rd International CBRNe Workshop 2016*. Villa Mondragone.
30. **Linney ACS**, **George Kernohan W**, **Higginson R.** The identification of competencies for an NHS response to chemical, biological, radiological, nuclear and explosive (CBRNe) emergencies. *Int Emerg Nurs*. 2011;**19**(2): 96–105.
31. **Hartsfield CW Jr**. How Has the Healthcare Preparedness Program Prepared Hospitals for Disasters? [M.B.A.]. United States -- Minnesota: The College of St. Scholastica; 2014.
32. **Gyllencreutz L**, **Carlsson C-P**, **Karlsson S**, et al. Preparedness for chemical, radiologic and nuclear incidents among a sample of emergency physicians' and general practitioners'—a qualitative study. *Int J Emerg Serv*. 2023 (ahead-of-print).
33. **Beikmohammadi S**, **Amir Heidari B**, **Dahesh T**, et al. Investigating the level of preparedness of Iranian hospitals against CBRN incidents: a case study of hospitals in West Azerbaijan Province. *Shiraz E-Med J*. 2023;**24**(7).
34. **Tong A**, **Sainsbury P**, **Craig J.** Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *Int J Qual Health C*. 2007;**19**(6):349–357.
35. **Australian Bureau of Statistics**. Snapshot of Queensland, High Level Summary Data for Queensland in 2021 Canberra: Commonwealth of Australia; 2022. Accessed 7 May 2021. https://www.abs.gov.au/articles/snapshot-qld-2021.
36. **Queensland Government**. Queensland Strategy for Disaster Resilience Brisbane: Queensland Government, Queensland Reconstruction Authority; 2023. Accessed 12 May 2023. https://www.qra.qld.gov.au/qsdr.
37. **Queensland Government**. Chemical Biological Radiological Annex to the Queensland Health Disaster Plan. In: *Health Q*, editor. Brisbane: Queensland Government; 2015: 43.
38. **Agency for Healthcare Research and Quality (AHRQ)**. Optimizing Surge Capacity Hospital Assessment and Planning. Rockville, Md.: Agency for Healthcare Research and Quality, U.S. Dept. of Health and Human Services; 2004.
39. **Burbach B**, **Barnason S**, **Thompson SA**. Using "think aloud" to capture clinical reasoning during patient simulation. *Int J Nurs Educ Scholarsh*. 2015;**12**(1):318–25. http://europepmc.org/abstract/MED/25719341 https://doi.org/10.1515/ijnes-2014-0044.
40. **Yin R.** Case study research: design and methods, 4th edition. *Can J Action Res*. 2009;**14**(1):69–71.
41. **Miles MB**, **Huberman AM**, **Saldana J.** *Qualitative Data Analysis - International Student Edition, A Methods Sourcebook, 4th Edition*. Sage Publications; 2019: 408.
42. **Annells M**, **Whitehead D.** Analysing data in qualitiative research. *Nurs Midwifery*. 2007:138–155.
43. **DeSantis L**, **Ugarriza DN**. The concept of theme as used in qualitative nursing research. *Western J Nurs Res*. 2000;**22**(3):351–372.
44. **System ET**. ETS Australia - Queensland: Emergo Train System; 2023. Accessed 3 June 2023. https://www.emergotrain.com/home/ets-australia-queensland.
45. **Australia M. Australasia MIMMS QLD** Courses: MIMMS Australia; 2016. Accessed 21 March 2021. https://www.mimms.org.au/courses/qld.
46. **Heslop D**, **Bushby T**, **New C**, et al. Framework for implementing and measuring interoperability and organizational change within and across a multi-service and multi-agency emergency response system. *Prehosp Disaster Med*. 2023;**38**(S1):s12–s.
47. **Gastaldi S**, **Horlait M.** Health care organizations' interoperability during multi-organizational disaster management: a scoping review. *Prehosp Disaster Med*. 2022;**37**(3):401–408.
48. **Schumacher L**, **Senhaji S**, **Gartner BA**, et al. Full-scale simulations to improve disaster preparedness in hospital pharmacies. *BMC Health Serv Res*. 2022;**22**(1).
49. **Noh J**, **Oh EG**, **Kim SS**, et al. Development and evaluation of a multimodality simulation disaster education and training program for hospital nurses. *Int J Nurs Pract*. 2020:e12810.
50. **Okudera H**, **Morita H**, **Iwashita T**, et al. Unexpected nerve gas exposure in the city of Matsumoto: report of rescue activity in the first sarin gas terrorism. *Am J Emerg Med*. 1997;**15**(5):527–528.

https://doi.org/10.1017/dmp.2024.151 Published online by Cambridge University Press

51. **Oktay C**, **Sayrac AV**, **Isik S**, et al. Personnel response during an internal emergency--unexpected release of an irritant gas in a hospital: [1]. *Workplace Health Saf.* 2013;**61**(9):381–383.
52. **Weeks B.** Training emergency department charge nurses through tabletop exercises. *Prehosp Disaster Med.* 2019;**34**(s1):s19–s.
53. **Barbash IJ**, **Kahn JM**. Fostering hospital resilience—lessons from COVID-19. *JAMA.* 2021;**326**(8):693–694.
54. **Clay-Williams R**, **Taylor N**, **Ting HP**, et al. The relationships between quality management systems, safety culture and leadership and patient outcomes in Australian emergency departments. *Int J Qual Health C.* 2020;**32**(Supplement_1):43–51.
55. **Azarmi S**, **Pishgooie AH**, **Sharififar S**, et al. Challenges of hospital disaster risk management: a systematic review study. *Disaster Med Public Health Prep.* 2022;**16**(5):2141–2148.
56. **Lake FR**, **Ryan G.** Teaching on the run tips 2: educational guides for teaching in a clinical setting. *Med J Austral.* 2004;**180**(10):527–528.
57. **Tobiano G**, **Murphy N**, **Grealish L**, et al. Effectiveness of nursing rounds in the Intensive Care Unit on workplace learning. *Intensive Crit Care Nurs.* 2019;**53**:92–99.
58. **Ranse J**, **Ituma OWN**, **Bail K**, et al. Disaster education in undergraduate nursing curriculum: a Delphi study to prioritise content for nursing students. *Collegian.* 2022;**29**(5):590–597.
59. **Ituma ON**, **Ranse J**, **Bail K**, et al. Disaster education for Australian nursing students: an integrative review of published literature to inform curricula. *Collegian.* 2022;**29**(1):93–99.
60. **Zahos H**, **Crilly J**, **Ranse J.** Psychosocial problems and support for disaster medical assistance team members in the preparedness, response and recovery phases of natural hazards resulting in disasters: a scoping review. *Australas Emerg Care.* 2022;**25**(3):259–266.
61. **Barnes A**, **Crilly J.** Review article: impact of pandemics on rural emergency departments: a scoping review. *Emerg Med Australas.* 2022;**34**(3):312–321.
62. **Sellers D**, **Crilly J**, **Ranse J.** Disaster preparedness: a concept analysis and its application to the intensive care unit. *Austral Crit Care.* 2022;**35**(2):204–209.
63. **Ali HM**, **Ranse J**, **Roiko A**, et al. Investigating organizational learning and adaptations for improved disaster response towards "Resilient Hospitals:" an integrative literature review. *Prehosp Disaster Med.* 2022;**37**(5):665–673.
64. **Wax RS**. Preparing the Intensive Care Unit for disaster. *Crit Care Clin.* 2019;**35**(4):551–62.
65. **Luke J**, **Franklin RC**, **Dyson J**, et al. & Building toward a disaster resilient health system: a study of hospital resilience. *Disaster Med Public Health Prep.* 2023;**17**:e219.
66. **Rebmann T**, **McPhee K**, **Haas GA**, et al. Findings from an assessment and inventory of a regional, decentralized stockpile. *Health Secur.* 2018;**16**(2):119–126.
67. **Standards Australia**. AS 4083 - 2010 Planning for Emergencies - Health Care Facilities. 3rd Edition. Canberra; 2010.
68. **Advanced Life Support Group (ALSG)**. Major Incident Medical Management and Support: The Practical Approach at the Scene, 4th Edition: Wiley-Blackwell; 2022.
69. **Queensland Health**. Queensland Health Disaster and Emergency Incident Plan, QHDISPLAN, August 2023. Brisbane: Queensland Government; 2023.
70. **Haverkort JJM**, **Biesheuvel TH**, **Bloemers FW**, et al. Hospital evacuation: exercise versus reality. *Injury.* 2016;**47**(9):2012–2017.
71. **Arora P**, **Gunaseelan R**, **Arora R.** Emerging trends in the management of disasters and mass casualty incidents. *CABI Reviews*. 2013(2013):1–4.
72. **Bhardwaj JR.** Chemical, biological, radiological, and nuclear disaster management. *J Pharm Bioallied Sci.* 2010;**2**(3):157–158.
73. **Eccles DW**, **Arsal G.** The think aloud method: what is it and how do I use it? *Qual Res Sport Exerc Health.* 2017;**9**(4):514–531.

https://doi.org/10.1017/dmp.2024.151 Published online by Cambridge University Press