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Hospital CBRN preparedness in Lebanon: a modified Delphi-based assessment tool

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ABSTRACT

Background Recent global events have highlighted an increasing risk of chemical, biological, radiological and nuclear (CBRN) incidents, emphasising the urgent need for enhanced preparedness in the health sector worldwide, especially in low-income countries where burden of exposure is high and limited resources pose significant challenges to effective response. This study aims to develop an assessment tool to evaluate hospital preparedness for CBRN incidents in Lebanon, a low-resource country at high risk for CBRN incidents.

Methods A two-round modified Delphi method was conducted on 21 January 2025 at the American University of Beirut Medical Center (AUB-MC) involving 11 subject matter experts with various expertise in the CBRN medical and public health fields. The experts used a weblink to vote on the inclusion of tool items, with a predefined consensus at 70% or higher.

Results Consensus was established for 88 items with the completion of the Delphi study representing 92% of the total number of items. The items were classified into nine essential categories for CBRN preparedness planning that included: facility information, policies and planning, governance, communication (internal/external), training, safety and security, decontamination, pharmaceutical countermeasures, recovery phase and post event management planning. Access to CBRN experts as part of response team, pharmaceutical inventory, gender-related cultural factors particularly in decontamination protocols and preparedness drills emerged as distinctive features within this assessment tool. Parameters concerning special populations and emergency medical services were excluded from the assessment tool.

Conclusion A comprehensive expert-developed hospital assessment tool for CBRN preparedness was created to enhance CBRN preparedness in resource-limited settings like Lebanon. The standarised tool facilitates the evaluation of Lebanese hospitals' readiness. It also guides policymakers and health authorities in developing targeted policies and strategic interventions to strengthen the health sector's CBRN incidents response capabilities.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Recent global events have highlighted the increasing risk of chemical, biological, radiological and nuclear (CBRN) incidents, emphasising the need for improved preparedness in global health sector. Existing CBRN hospital preparedness assessment tools are primarily developed for high-income countries (HICs), raising generalisability concerns especially to low-resource settings.

WHAT THIS STUDY ADDS

⇒ This study used the modified Delphi expert-driven method to develop hospital-based CBRN assessment tool tailored to low-resource settings like Lebanon. The tool emphasises vital categories for CBRN preparedness planning and includes unique features such as the inclusion of CBRN experts in response teams, comprehensive pharmaceutical inventory and extensive drills. It also highlights specific cultural factors concerning gender as significant within the Lebanese context, particularly regarding decontamination protocols.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The tool facilitates the assessment of hospitals' readiness and can guide policymakers and health authorities in targeted resource allocation and intervention planning within low-resource contexts.

INTRODUCTION

Chemical, biological, radiological and nuclear (CBRN) incidents often result in a large number of casualties and create hazardous environments in a very short period of time.[1] Recent global events have highlighted an increasing risk of CBRN incidents, emphasising the urgent need for enhanced preparedness in the health sector worldwide.[2–4] These incidents, whether intentional, accidental or stemming from emerging diseases like Ebola or COVID-19, pose significant environmental and public health risks, exacerbated by technological advancements and evolving warfare strategies.[5] The risk is particularly acute in low- and lower-middle-income countries (LIC/LMICs), where limited resources, infrastructure and expertise often hinder effective preparedness and response.[6]

In recent years, there have been multiple CBRN incidents in the LIC/LMIC in the Middle East. Syria experienced several chemical attacks resulting in thousands of deaths and injuries. The physiological and psychological trauma experienced by the affected population has amplified the burden on Syria's fragile health system.[7] Additionally, Lebanon, a country that has faced significant political and security challenges recently, experienced the largest

non-nuclear blast in modern history. This occurred when 2750 tons of ammonium nitrate detonated at the Beirut port leading to 200 fatalities, more than 6000 injuries and 300 000 people displaced.[8 9] Moreover, during the recent conflict with Israel in 2024, Lebanon experienced 1768 attacks using flare, incendiary and white phosphorus bombs, resulting in approximately 351 forest fires, with devastating environmental damage and public health risk.[10]

Effective preparedness and response to CBRN incidents necessitate the collaboration of multiple stakeholders, such as government agencies, healthcare systems and international organisations.[11] Hospitals, critical components of emergency healthcare systems, play a central role in managing CBRN casualties.[12] The challenges associated with CBRN agents are distinct from those related to other mass casualty incidents (MCI), demanding special consideration in both planning, facility preparedness and training.[10 11 13] Even though LIC/LMICs have experienced some of the deadliest CBRN incidents and disasters, their CBRN disaster planning often remains inadequate, especially at the hospital level.[11 14] While most high-income countries (HICs) have an integrated healthcare system that includes a robust CBRN response that starts at the prehospital level and filters some of the load arriving to hospitals, many LMICs have less developed prehospital services, leading to hospitals' having to shoulder much of the triaging and care responsibility.[15 16] Assessing the level of hospital CBRN preparedness is therefore paramount, especially in LIC/LMICs.

The body of literature on CBRN hospital preparedness assessment tools primarily features studies from HIC, illustrating a significant geographical focus.[17–19] While some efforts have produced comprehensive evaluations using structured methodologies, a notable limitation is the lack of attention to low-resource settings, which are rarely addressed in existing research. Additionally, many studies concentrate on narrow aspects of CBRN preparedness, rather than providing a comprehensive evaluation. This issue is compounded by the reliance on unvalidated surveys in various instances. There is an urgent need for a comprehensive and well-structured tool specifically developed for low-resource settings, which are often more susceptible to CBRN incidents.

The aim of this study is to design and develop a CBRN assessment tool for hospitals' preparedness in Lebanon.

METHODS

A two round anonymised modified Delphi study was conducted in-person on 21 January 2025 at the American University of Beirut Medical Center (AUB-MC) to develop the assessment tool. The panel included 11 subject matter experts (SMEs) covering the diverse range of expertise relevant to CBRN preparedness and response specific to the Lebanese context. This list of disciplines and experts was put together in consultation with the Lebanese National Commission on CBRN Hazards. Specifically, the panel included three emergency medicine experts: one serving as a physician director, another as professor of emergency medicine and a third as an associate professor and director of operations with clinical toxicology expertise. Additional members included an occupational safety officer, a chemical engineer who is also a member of the National CBRN Commission and an infectious disease specialist. Further contributions came from the commander of the CBRN unit at the Lebanese Armed Forces, a nurse leader for clinical affairs, a CBRNE specialist working with the Lebanese Red Cross, a civil defence member who had undergone CBRN training and a CBRN expert from the ministry of public health.

A preliminary assessment tool was developed by the research team based on a thorough literature review using Medline-Ovid with the following key terms: 'Hospital preparedness', 'CBRN', 'Chemical warfare agents', 'tear gases', 'decontamination', 'protective clothing', 'gloves', 'emergency preparedness', 'respiratory protective devices', 'radioactive hazard release', 'radiation injuries', 'radiation protection', 'radiation-protective agents', 'radioactive hazard release', 'bioterrorism', 'biological warfare', 'chemical terrorism', 'hazardous substances', 'containment of biohazards' and 'disaster'. Followed by screening for relevant articles from which components to CBRN hospital preparedness were extracted. The process was also guided by the WHO Hospital Safety Index Guide for Evaluators. The preliminary assessment tool included 79 assessment items focused on various aspects of hospital preparedness and response categorised into nine categories.

The SMEs were approached through an introductory email outlining the project's objectives, the voluntary nature of participation, assurance of confidentiality and an emphasis on providing a written informed consent as a prerequisite before participation. After which, they were directed to a secure anonymised online platform (LimeSurvey) that included the preliminary assessment tool. They were asked to review the provided parameters and submit additional suggestions for parameters they considered essential for the assessment of CBRN preparedness and response prior to the commencement of the in-person rounds. The final assessment tool included a list of 96 parameters classified into nine categories as follows: facility information, policies and planning, governance, communication (internal/external), training, safety and security, decontamination, pharmaceutical countermeasures, recovery phase and post event management planning. The assessment tool needed approximately 20–30 min, on average, to be completed.

The assessment tool was then further modified by the SME panel through two in-person Delphi session rounds. In round 1, experts voted (Yes/No) on the inclusion of proposed parameters for evaluating hospital preparedness and response during a potential CBRN incident, with a consensus threshold set at 70% agreement among participants. Parameters that did not meet the threshold were deliberated on and revised based on experts' feedback. After the discussion round, the experts modified or added additional parameters to the tool. In round 2, the revised parameters were then resubmitted for a final vote for inclusion or exclusion based on the same predefined consensus threshold. After round 2, parameters that still did not meet the ≥70% agreement threshold were excluded from the final set. Voting was performed online using the anonymised online platform (LimeSurvey) for each round to minimise bias. All responses were collected and analysed by an independent data manager blinded to participants' identities and aware of the predefined consensus threshold.

Statistical analysis

LimeSurvey provided data on consensus for each individual parameter during the Delphi rounds, while Microsoft Excel was used to calculate and display the percentage of questions within each category that met the consensus threshold.

Patient and public involvement

Patients and members of the public did not participate in this research.

RESULTS

The committee worked collaboratively to finalise the assessment tool. All selected experts (n=11) successfully completed the

two Delphi rounds. The respondents included seven men and four women.

The initial assessment tool included 96 parameters across various categories, demonstrated increasing consensus from Round 1 to Round 2. In Round 1, 82 parameters achieved a consensus level of ≥70%. Round 2 showed an improvement, with 88 parameters reaching the consensus threshold.

Following Round 1, a subset of parameters (n=14) pertaining to hospital preparedness and response to CBRN incidents failed to achieve the predefined consensus threshold of ≥70%. These parameters focused on various critical areas, including laboratory and diagnostic preparedness, special populations preparedness, occupational preparedness, staff accommodation planning, staff training and cultural competency, equipment, radiation source management, staff safety, policy operational preparedness, data management, ethics, planning preparedness, resource and equipment preparedness, operational response capacity, response infrastructure and response safety and inclusivity. Of the initial 14 parameters failing to reach the consensus threshold in Round 1, eight remained below the level of consensus in Round 2. The six parameters addressing data management, ethics, planning preparedness, resource and equipment preparedness, operational response capacity, response infrastructure and response safety and inclusivity were revised and modified based on experts' feedback and subsequently included in the assessment tool. No further rounds of Delphi sessions took place.

The final assessment tool initially comprised 88 parameters that were subsequently reorganised into 60 parameters with subdomains distributed across nine comprehensive categories: facility information, policies and planning, governance, communication (internal/external), training, safety and security, decontamination, pharmaceutical countermeasures, recovery phase and post event management planning. The level of consensus regarding the items in the two modified Delphi cycles is presented in table 1.

The full set of parameters can be found in online supplemental appendix 1.

DISCUSSION

CBRN incidents are infrequent but high-impact attack scenarios. The increasing risk of CBRN incidents within contexts like Lebanon requires intense preparedness efforts. As such, our study used the modified Delphi method, a multidisciplinary approach that helps minimise bias,[20] to develop an assessment tool to evaluate hospital preparedness for CBRN incidents contextualised to a low resource setting. The items that achieved consensus covered essential categories for CBRN preparedness planning including facility information, policies and planning, governance, communication (internal/external), training, safety and security, decontamination, pharmaceutical countermeasures, recovery phase and post event management planning. The inclusion of CBRN experts in response teams, pharmaceutical inventory, gender-related cultural factors particularly in decontamination protocols and comprehensive drills appeared as unique features of this tool. However, parameters related to emergency medical services (EMS) and special populations were de-emphasised by SMEs because they did not agree on their applicability in a resource-limited setting.

Existing assessment tools that have been developed and shared in peer-reviewed literature[17–19 21] mostly originate from HIC settings, raising generalisability concerns for low-resource

Table 1 Level of consensus in the two Delphi cycles

Category	Total number of parameters (n)	Delphi cycle I—% of parameters ≥70% consensus	Delphi cycle II—% of parameters ≥70% consensus
Facility information			
Overall	4	100 (4)	100 (4)
Risk assessment	3	100 (3)	100 (3)
Infrastructure	3	100 (3)	100 (3)
Policies and planning			
Overall	21	76 (16)	81 (17)
Hazard specific planning	2	100 (2)	100 (2)
CBRN triage	1	100 (1)	100 (1)
Ethics	1	0 (0)	100 (1)
Special population care	1	0 (0)	0 (0)
Coordination with external stakeholders	6	100 (6)	100 (6)
Governance			
Overall	2	100 (2)	100 (2)
CBRN expertise	8	100 (8)	100 (8)
Communication (internal/external)	5	100 (5)	100 (5)
Training	9	100 (9)	100 (9)
Safety and Security			
PPE	5	80 (4)	100 (5)
Equipment	3	67 (2)	100 (3)
Waste management	2	50 (1)	50 (1)
Decontamination	9	56 (5)	78 (7)
Pharmaceutical countermeasures	6	100 (6)	100 (6)
Recovery phase and post event management planning	5	100 (5)	100 (5)
Total (n)	96 parameters	82 parameters	88 parameters

CBRN, chemical, biological, radiological and nuclear; PPE, personal protective equipment.

contexts. Additionally, most focus on one or two aspects of CBRN incidents and as such are not comprehensive of all CBRN elements concepts. Furthermore, existing studies offer little background on the range of experts included within the Delphi methods. This study represents the first comprehensive assessment of CBRN preparedness and response elements in a low resource setting, engaging a diverse group of SMEs, including hospital-based stakeholders, clinicians as well as governmental CBRN experts. Through a rigorous approach, an assessment tool contextualised to the challenges of the LIC/LMIC setting was developed.

An important theme emerging from our study was the vital role of integrating CBRN experts into preparedness and response plans to enhance both risk assessment and response capabilities. This was uniquely identified by the SMEs, who focused on the importance of including specific questions within the assessment tool that focused on the availability of specialised experts such as clinical toxicologists, infectious diseases and radiation specialists, for guidance on preparedness and response. Experts felt that such expertise needed to be available, whether in-house or as an accessible on-call resource, given the limited specialised CBRN expertise available at most hospitals within a low-resource context. This reinforces both the assessment and strategic response capabilities, ensuring optimal readiness of hospitals to CBRN threats.[22]

Notably, our tool compared with other tools has an extensive section on drills, addressing all aspects of CBRN training, ensuring a wide range of potential threat scenarios are addressed. Experts considered that this all-hazards approach was critical given the region's status as a conflict zone, where diverse threats are prevalent. In Lebanon, where diverse threat scenarios exist due to ongoing conflicts and geopolitical instability,[23 24] limiting training to only chemical or radiological incidents may leave responders unprepared for other critical hazards.

Effective CBRN management requires a coordinated effort across multiple agencies. Key participants in such responses typically include EMS, who play a central role in the multiservice effort.[25] Most HICs have well-structured EMS with established protocols for efficient management of CBRN victims. The prehospital care services in these settings typically include triage, treatment, monitoring and decontamination, ensuring the safety of victims and responders alike.[26] In contrast, prehospital care services in many LMICs—including Lebanon—primarily focus on transportation while lacking established protocols for field triage or care or mechanisms to coordinate closely with hospitals.[27 28] While recent national efforts in Lebanon have included CBRN training for prehospital personnel, CBRN response and care protocols have not been widely integrated into their practice, shifting the burden of decontamination and care of CBRN victims almost entirely to the hospitals. Accordingly, the SMEs felt that questions concerning prehospital care within the Lebanese context were not key to a hospital CBRN assessment tool, given their limited role.

Given the limited role of EMS services in decontamination, stabilisation and care of CBRN victims, and the greater care burden shouldered by hospitals, our SMEs considered hospital pharmaceutical preparedness a key consideration within the assessment tool. Unlike most tools that only consider a limited range of pharmaceutical agents,[17–19] the final tool that emerged from this study included a comprehensive list of pharmaceutical agents, enabling a complete evaluation of hospitals' medication stockpiles. This included agents related to six main areas including biological agents, nerve agents, heavy metals, choking agents, blistering agents and benzodiazepine/opioids.

While many other tools have developed parameters for special populations, these questions were deprioritised in our tool. SMEs felt that within LIC/LMIC settings, hospitals often have limited capacity and bandwidth to implement age and culture-based care protocols for special populations. At the same time, certain cultural considerations related to gender were considered important within the Lebanese context, especially those related to decontamination protocols. While fully removing one's clothes is essential for mitigating CBRN exposures, it is crucial to balance this with respect for human dignity and cultural sensitivities. Lebanon's society is characterised by conservative cultural norms that emphasise privacy. Accordingly, it is important for healthcare providers to establish a trusting relationship with patients by ensuring their privacy as far as possible and offering alternatives when appropriate, while also maintaining sensitivity to religious and cultural norms during decontamination procedures.[21 29–31]

The study highlights the need for the development of a comprehensive CBRN assessment tool addressing all potential risks faced in a high conflict zone with limited resources. The developed tool can be used to assess Lebanese hospitals' current preparedness, filling an important knowledge gap that exists today in this area. The assessment tool can guide policymakers and health authorities with the development of targeted policies and strategic interventions aimed at strengthening the health sector's capacity to effectively manage CBRN incidents. Ultimately, this tool aims to enhance overall preparedness, improve coordination among stakeholders and ensure a more resilient health system capable of protecting populations in the event of CBRN incidents.

LIMITATIONS

This study has several limitations that need to be acknowledged. First, the SMEs involved in the development of the tool were selected from the local Lebanese context. As such, the tool primarily reflects practices and considerations relevant to Lebanon. Notably, experts from HICs were not included in this process; therefore, there was no input from practices or protocols typical of HIC settings. While many of the Lebanese experts had received training in various resource environments, the lack of direct HIC perspectives limits the scope of practice integration. Second, the developed tool is highly contextualised to Lebanon's specific cultural, institutionaland infrastructural landscape. As a result, its applicability to other LIC/LMICs with differing societal norms, healthcare systems or infrastructure may be limited. Lastly, the tool has not yet undergone field testing or validation, which is necessary to assess its practical utility, reliability and effectiveness in real-world settings. Future validation efforts are essential to ensure its suitability and adaptability across diverse low-resource contexts.

CONCLUSION

This study successfully developed a comprehensive hospital assessment tool specifically designed to enhance CBRN preparedness in resource-limited settings like Lebanon. Recognising the unique challenges posed by CBRN incidents, the tool emphasises the integration of expert knowledge with a thorough evaluation of pharmaceutical countermeasures. Although a consensus was not reached for some parameters related to EMS and accessibility, the tool offers policymakers and health authorities a valuable framework for assessing and improving hospital readiness. Ultimately, this initiative aims to strengthen healthcare resilience

and better protect populations from the complex impacts of CBRN incidents.

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Contributors The authors contributed to the study as follows: EH, ZK, and TEZ conceptualized the study. Methodology was developed by ZK. GC performed literature review. Data collection and analysis was completed by GC. EH, ZK, TEZ, AK, EA, NB, RJ, and GC contributed to the development and refinement of the assessment tool. EH and ZK supervised the data analysis. Project administration was managed by EH. The original draft was written by EH, ZK, TEZ, and GC with major editing completed by EH. All authors read, reviewed and approved the final manuscript. EH is responsible for the overall content as guarantor.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study was approved by the American University of Beirut's Institutional Review Board (IRB) (approval No. SBS-2024-0089). Participants gave informed consent to participate in the study before taking part.

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