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# Health care system hazard vulnerability analysis: an assessment of all public hospitals in Abu Dhabi

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*Hazard vulnerability analysis (HVA) is used to risk-stratify potential threats, measure the probability of those threats, and guide disaster preparedness. The primary objective of this project was to analyse the level of disaster preparedness in public hospitals in the Emirate of Abu Dhabi, utilising the HVA tool in collaboration with the Disaster Medicine Section at Harvard Medical School. The secondary objective was to review each facility's disaster plan and make recommendations based on the HVA findings. Based on the review, this article makes eight observations, including on the need for more accurate data; better hazard assessment capabilities; enhanced decontamination capacities; and the development of hospital-specific emergency management programmes, a hospital incident command system, and a centralised, dedicated regional disaster coordination centre. With this project, HVAs were conducted successfully for the first time in health care facilities in Abu Dhabi. This study thus serves as another successful example of multi-disciplinary emergency preparedness processes.*

**Keywords:** Abu Dhabi, disaster, disaster planning, emergency management, emergency preparedness, hazard vulnerability analysis, United Arab Emirates

## Introduction

The disasters of the past decade have led health care systems worldwide to accord increasing priority to emergency management. Over the past few years in particular, disasters—both manmade and natural—have forced health care professionals to confront the vulnerabilities of their emergency preparedness systems and to begin embracing better practices to improve their ability to manage disasters.[2] Despite this work, significant disparities—and deficits in coordination—exist between various hospitals in terms of the quality of emergency management, leading to a duplication of efforts and unnecessary costs.

The regionalisation of health care-related emergency preparedness has been proposed as a possible way forward. This idea has been implemented locally in Massachusetts and in the Washington, DC, metropolitan area, as well as in countries such as Canada and New Zealand, with positive outcomes related to networking, coordination, standardisation and centralisation of health preparedness practices (Grieb and Clark, 2008; Koh et al., 2008; Lewis and Kouri, 2004; Stoto and Morse, 2008). Furthermore, a


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regionalised structure allows for increased levels of training, standardisation and co-ordination of protocols and processes within the emergency management system, which, in turn, produces more efficient systems (Krimmel, 1997). This model was recently adopted in Abu Dhabi, the capital of the United Arab Emirates (UAE), with the establishment of the Abu Dhabi Health Services Company (SEHA).

The Emirate of Abu Dhabi occupies an area of about 67 square kilometres; in mid-2012, it was home to an estimated 2.3 million inhabitants (SCAD, 2013). The emirate itself is comprised of three distinct regions: Abu Dhabi city, Al Ain (the eastern region) and Al Gharbia (the western region). SEHA is tasked with managing and developing the emirate's public hospitals and clinics. As part of international collaborations between Abu Dhabi and international organisations, Harvard Medical School has partnered with SEHA to carry out the first hazard vulnerability analysis of health facilities in UAE, and probably in the region.

Abu Dhabi commits vast amounts of capital to ensure that the medical care it provides is of the highest quality. The preparation for and response to disaster events is addressed utilising SEHA's health care expertise and resources. Fortunately for Abu Dhabi, experience with actual disasters has been limited. In contrast, the Disaster Medicine Section in the Division of Emergency Medicine at Harvard Medical School is comprised of health care professionals who have national and international disaster response and management experience and expertise. The goal of the collaboration was to bring that expertise to the well-organised and extensive health care system in Abu Dhabi. This interaction between an academic and a non-academic institution was also intended to enhance implementing interventions and increase their effectiveness.

An important first step in developing a comprehensive all-hazards approach to disaster preparedness and response, given limited resources and variable risk to different types of disasters, is risk stratification and an evaluation of preparedness needs using a hazard vulnerability analysis (HVA). An HVA is used to identify potential threats systematically; rate the probability of those threats; estimate their impact on a given organisation or region and its resources; and then calculate a relative risk for the organisation or region for such events. This information can be used to guide the development of planning, mitigation and response strategies in a health care facility or community in a way that matches risk with the utilisation of resources. In its chapter on emergency management, the Joint Commission on hospital accreditation states that hospitals conduct HVAs and update them at annual reviews (Joint Commission, 2009).

Other terms that have been used to describe this process include risk assessment, risk analysis, hazard analysis, threat assessment and vulnerability assessment. In some situations, HVAs have focused on specific types of hazards. The US Veterans Health Administration, for example, developed hazard and exposure assessments for its hospitals in response to chemical terrorism (Georgopoulos et al., 2004). Meanwhile, some hospitals have focused mainly on bioterrorism (Schultz, Mothershead and Field, 2002); still others concentrate on internal disasters, defined as hazardous events that disrupt operations and that have a direct impact on the hospital's service capabilities (Aghababian et al., 1994).

Two of the most commonly used tools for conducting HVAs are the Medical Center Hazard and Vulnerability Analysis tool, developed by Kaiser Permanente (KP), and the American Society for Healthcare Engineering HVA. The KP HVA tool was utilised for this project as it is easily accessible and widely available, is being used in the Harvard health care system and many parts of the world, and provides a common basis from which to compare data and share results (Campbell, Trockman and Walker, 2011).

The KP HVA tool can be used to produce a quantitative assessment that provides a score (percentage) and graphical representation of hazard-specific relative risk. This tool also allows probability, impact, preparedness, response, resources and risk for hazard categories—whether natural, technological, human or hazardous material (hazmat)—to be evaluated and prioritised.

The primary objective of this project was to analyse the level of disaster preparedness in all public hospitals of Abu Dhabi by utilising the HVA tool and through collaboration with the Disaster Medicine Section at Harvard Medical School. The secondary objective was to review existing disaster plans currently in use at those facilities and make recommendations based on the HVA findings. Joint work as a hospital system—rather than a group of individual facilities—and the use of a standardised format was expected to help health care facilities identify and stratify potential hazards and vulnerabilities. This approach was also designed to help identify areas of strength and weaknesses regarding preparedness, mitigation and response; in that way, it allows for planning for all hazards based on scientific and objective data.

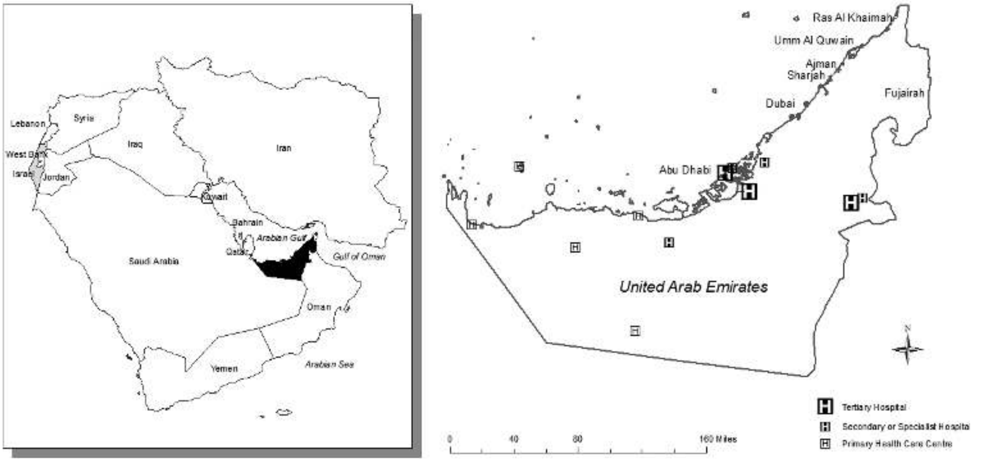
## Methods

A standardised and comprehensive HVA was conducted from September to November 2008 at all 12 public hospitals in the Emirate of Abu Dhabi utilising the KP HVA tool. Figure 1 shows the wide distribution of the surveyed hospitals in and around the following regions:

- **Abu Dhabi city:** Al Corniche Hospital, Al Mafraq Hospital, Al Rahba Hospital and Sheikh Khalifa Medical City;
- **Al Ain:** Al Ain Hospital and Tawam Hospital; and
- **Al Gharbia:** Al-Marfa Hospital, Al Sila Hospital, Dalma Hospital, Ghayathi Hospital, Liwa Hospital and Madinat Zayed Hospital.

The completed KP HVA was used to compute a relative risk score (percentage) with reference to different hazards for each health care facility. The level of emergency preparedness of a facility against a particular hazard was determined according to the preparedness scores in the KP HVA tool. The public hospitals were divided into primary, secondary and tertiary facilities to facilitate a comparison across hospital categories. The relative risk score (percentage) was computed for all hazards for each facility, as were mean scores of preparedness against possible disasters in each hazard

**Figure 1.** Locations of participating facilities in the Emirate of Abu Dhabi




Source: courtesy of Khaula Alkaabi, Geography and Urban Planning Department, College of Humanities and Social Sciences, United Arab Emirates University.

classification (natural, technological, human, and hazmat). The level of emergency preparedness against any hazard at a particular level of health care—primary, secondary and tertiary—was then computed as a mean score of preparedness. The ranges of mean scores were accorded the following levels of emergency preparedness:

- high: 1.00–1.67;
- moderate: 1.68–2.34;
- low: 2.35–3.00.

A panel of experts in the fields of disaster medicine and emergency management developed reports that focus on the process of the HVA as conducted by each facility; they also conducted limited reviews of facility disaster plans. General observations were collated and recommendations for improvement were generated.

## Results

The KP HVA tool is divided into four categories of hazard: natural, human, technological, and hazmat. Of the 12 public hospitals, 8 reported technological hazards as their highest risk category; 3 identified human hazards as the highest risk; and only 1 cited hazmat hazards (including chemical, radiological and nuclear exposures). All hospitals ranked natural hazards as the lowest or second-lowest threat to their facility (see Tables 1 and 2). The natural hazards category includes temperature extremes, epidemics and earthquakes.

All types of public health facilities should have been prepared against natural hazards, yet tertiary health care centres were best prepared for temperature extremes. All facilities were similarly prepared against epidemics, tornadoes and earthquakes (see Table 3).

Asked to identify threats posed by technological hazards, all public health care facilities cited internal fires as well as potential failures involving communications, electricity, fire alarms, generators, information systems, sewage, and water. Tertiary hospitals were better prepared for electricity, generator and water failure as compared to other hazards in this category. Secondary and primary health care centres also cited transportation failure and fuel shortage among the technological hazards that warranted preparedness.

With reference to human hazards, all public hospitals of Abu Dhabi included preparedness for mass-casualty incidents (meaning trauma and medical or infectious events) and forensic admission. Emergency preparedness for mass casualty trauma

**Table 1.** Hospital ranking of hazard risk levels

| Type of hazard | Number of facilities ranking risk as: | | | |
|---|---|---|---|---|
| | Highest | Second highest | Third highest | Lowest |
| Natural hazard | 0 | 0 | 4 | 8 |
| Human hazard | 3 | 4 | 4 | 1 |
| Technological hazard | 8 | 3 | 1 | 0 |
| Hazmat hazard | 1 | 5 | 3 | 3 |

Source: authors.

**Table 2.** Relative hazard risk, by hospital and hazard category

| Type of health care facility | Hospital name | Relative risk scores per hazard | | | |
|---|---|---|---|---|---|
| | | Natural | Technological | Human | Hazmat |
| Tertiary hospitals | Al Mafraq Hospital | 11% | 36% | 29% | 19% |
| | Shaikh Khalifa Medical City | 20% | 36% | 37% | 29% |
| | Tawam Hospital | 4% | 9% | 26% | 10% |
| Secondary and specialist hospitals | Al Ain Hospital | 15% | 36% | 32% | 33% |
| | Al Corniche Hospital | 20% | 53% | 31% | 39% |
| | Al Rahba Hospital | 9% | 11% | 10% | 22% |
| | Madinat Zayed Hospital | 5% | 22% | 18% | 16% |
| Primary hospitals | Al Marfa Hospital | 6% | 29% | 23% | 4% |
| | Al Sila Hospital | 6% | 19% | 13% | 2% |
| | Dalma Hospital | 17% | 21% | 10% | 20% |
| | Ghayathi Hospital | 7% | 24% | 18% | 20% |
| | Liwa Hospital | 10% | 16% | 17% | 7% |

Source: authors.

**Table 3.** Emergency preparedness scores per type of health care facility and hazard*

| Hazard type | | Mean preparedness score per type of health care facility | | |
|---|---|---|---|---|
| | | Tertiary | Secondary | Primary |
| Natural | Drought | – | 2.25 | 1.60 |
| | Earthquake | 2.33 | 2.50 | 2.80 |
| | Epidemic | 2.33 | 1.50 | 2.60 |
| | Temperature extremes | 1.25 | 2.25 | 1.80 |
| | Thunderstorm, severe | 2.67 | 2.75 | – |
| | Tornado | 2.33 | – | – |
| Technological | Communications failure | 2.33 | 2.50 | 2.40 |
| | Electrical failure | 1.66 | 1.50 | 1.60 |
| | Fire alarm failure | 2.00 | 2.25 | 1.40 |
| | Fire, internal | 2.00 | 1.75 | 1.60 |
| | Flood, internal | 2.00 | – | 2.40 |
| | Fuel shortage | – | 2.50 | 1.80 |
| | Generator failure | 1.66 | 1.75 | 2.00 |
| | Hazmat exposure, internal | 2.00 | 2.00 | – |
| | Heating, ventilation, and air conditioning failure | – | – | 2.00 |
| | Information systems failure | 2.00 | 2.00 | 2.40 |
| | Medical gas failure | 2.00 | 1.75 | – |
| | Medical vacuum failure | – | 1.25 | – |
| | Sewer failure | 2.33 | 2.00 | 1.80 |
| | Structural damage | 2.33 | – | – |
| | Supply shortage | 2.00 | 2.50 | – |
| | Transportation failure | – | 2.00 | 2.60 |
| | Water failure | 1.66 | 1.50 | 1.60 |
| Human | Bomb threat | X | X | X |
| | Civil disturbance | X | X | X |
| | Forensic admission | 2.33 | 1.50 | 2.60 |
| | Hostage situation | X | X | X |
| | Infant abduction | X | X | X |
| | Labour action | X | X | X |
| | Mass casualty incident (medical or infectious) | 2.33 | 2.00 | 2.80 |
| | Mass casualty incident (trauma) | 1.33 | 2.25 | 2.80 |
| | Terrorism, biological | X | X | X |
| | VIP situation | X | X | X |

| Hazard type | | Mean preparedness score per type of health care facility | | |
|---|---|---|---|---|
| | | Tertiary | Secondary | Primary |
| Hazardous materials | Chemical exposure, external | X | X | X |
| | Hazmat incident with mass casualties (>5 victims) | – | 2.00 | – |
| | Hazmat incident with limited casualties (<5 victims) | – | 1.50 | – |
| | Internal spill, large | 2.00 | 2.50 | – |
| | Internal spill, small–medium | 1.33 | 1.75 | 2.40 |
| | Radiological exposure, external | X | X | – |
| | Radiological exposure, internal | 1.33 | 1.75 | X |
| | Terrorism, chemical | X | X | X |
| | Terrorism, radiological | X | X | X |

Notes:
– No level of preparedness.
* Mean scores of emergency preparedness levels: high: 1.00–1.67; moderate: 1.68–2.34; low: 2.35–3.00.
X=results not shown because of security implications.
Sources: authors.

incidents was best in tertiary-level hospitals, while it was moderate in primary and secondary care centres.

All public health care facilities identified small–medium-sized internal spills as the only hazmat hazard warranting emergency preparedness; in this category, tertiary and secondary hospitals were better prepared than primary health care centres.

Individual reports were generated and given to each hospital highlighting the strengths and weaknesses of their specific HVA process and facility disaster plan. Results of hazards and disasters with security implications for Abu Dhabi (human and hazmat hazards) were not discussed in this article.

## Discussion

From a system-wide perspective and based on the review of the 12 hospitals' HVA tools and current disaster plans, eight observations were made regarding both the health care facility level and the health care system level of Abu Dhabi.

### Observation 1: need for accurate data

The general lack of accurate data prevents teams from estimating hazard probabilities effectively. Although information on past events at a facility—especially regarding natural hazards—can often be gathered from various sources, including local residents and hospital archives, such sources are of varying reliability. Reporting periods may overlap, recording periods may be interrupted and there is a lack of well-defined reference levels. These problems made the probability estimation and analysis of data difficult and led to inconsistencies in the data reviewed.

## Observation 2: need for better risk assessment

Some events seemed to be underestimated in terms of probability and impact. The probability of certain events was rated low despite available data to support higher probability, as evidenced by the assessment of vulnerability related to earthquakes and seismic activity. Objective data available to the reviewers included information from the National Center of Meteorology and Seismology in UAE, which reported all seismic activity from 2004 to 2008. The reviewers' analysis of this data revealed that the area sustains 60 or more earthquakes annually, some as high as 6.0 on the Richter scale; the potential for disaster is therefore significant. Consequently, the HVA rating of earthquakes as having a 'low probability' does not represent an accurate estimate of the likelihood of this type of event. This type of misjudgement was reflected in the general preparedness for earthquakes, which was low (mean score $\geq 2.33$) at all levels of health care. Other examples of the underestimation of vulnerability related to fuel shortages, transportation failures, steam failures and floods, all of which were presented as events that 'never' happen despite the fact that a significant earthquake could result in any of them.

## Observation 3: need for an 'all-hazards' approach

There is a manifest need for Abu Dhabi's public hospitals to shift from the 'hazard-specific' to an 'all-hazards' approach in disaster planning. 'All-hazards' does not imply preparedness for any and all hazards; rather, it calls attention to the situations and needs that emerge across different types of emergency. One example is the need for emergency notification or mass evacuation of the local population. The all-hazards approach can be taken in a general disaster plan, which is designed to guide the response to various unexpected events. Yet whereas such all-hazards plans can provide a basic response framework, planners should prioritise responses to disasters that pose a higher risk for the organisation based on HVA reports.

All-hazards planning offers the added benefit of being cost-effective in terms of time and money. The development of a single all-hazards plan will ultimately enhance the efficiency of an organisation, even if multiple appendices must be added to provide guidance for dealing with specific issues. As an example, hazmat accidents require an understanding of the chemicals involved as well as technical expertise in processes developed to minimise damage and protect lives. Structural failures raise other issues concerning the conduct of emergency response in unstable and unsafe environments. Floods raise public health issues with regard to sanitation, hazmat and additional structural issues. In view of such risks, all-hazards planning encourages a broader perspective from which to build effective programmes to manage hazards and disasters.

## Observation 4: need for emergency management programmes

Emergency preparedness against hazards was not uniform across the surveyed facilities. In some cases, preparedness even varied within the three health care levels, such as when one or more hospitals failed to recognise a particular hazard as a threat. For example, hospitals close to coastal areas considered external floods a threat and acknowledged the need for corresponding emergency preparedness; however, inland health centres did not see flooding as a hazard for their facility. Emergency preparation for epidemics also varied across facilities, with primary health care centres better prepared than tertiary hospitals. To reduce such variations and ensure uniformity in emergency preparedness, health care authorities must develop standardised emergency management programmes for each health care facility.

As part of the all-hazards approach, emergency management programmes cover definitions, management guidelines and objectives; performance indicators; and monitoring and evaluation procedures. A robust programme identifies key emergency management positions and their responsibilities; sets work priorities; covers plans for training, drilling, and exercising; and serves to guide planning, mitigation and recovery projects. Such a programme is designed to focus internal resources on all aspects of the emergency management cycle.

## Observation 5: need for hospital incident command systems

If all hospital departments are to be properly integrated into the emergency response programme, then a hospital incident command system must be implemented in each facility. Such a system builds in flexibility that relies on the necessary response components; it can be utilised for both small and large events. Each position on the organisational chart is assigned a mission, with immediate, intermediate and extended tasks detailed on corresponding job action sheets.

The hospital incident command system allows for the identification and activation of appropriate staff and resources, while also providing a clear chain of command and accountability. It promotes an organised and structured response to any type of event. In addition, it facilitates communication throughout the system, since all stakeholders operate from a common type of organisational response system, using a common language and approach.

## Observation 6: need for external stakeholder involvement

Despite the very encouraging participation of many internal disciplines in the HVA process and in the disaster plan reviews, there appeared to be no participation from other important external local agencies that are critical in disaster planning. These stakeholders include the police, the fire department and emergency medical services. Input from civic agencies could also prove to be very useful as cooperation with them can lay the groundwork for future mutual aid agreements and collaboration. Moreover, the enhanced involvement of external stakeholders is key to the coordinated sharing of resources in case of a disaster.

### Observation 7: need for better decontamination capabilities

The Emirate of Abu Dhabi is experiencing rapid growth, which is expected to bolster the economic and social development of the residents, enhance infrastructure and promote investment. Much of this growth is tied to the expansion of the petrochemical industry, which puts hospitals in the region at a heightened risk of hazmat incidents. As a result, there is an urgent need to fund and support pre-admission patient decontamination capabilities in the health care system. This includes buying equipment, training personnel, running practice exercises and evaluating any programmes to be incorporated into the regional hazmat plans. The purchase of decontamination equipment is not sufficient; training of personnel in the use of such equipment must be among the tasks of an emergency management team.

### Observation 8: need for a regional disaster coordination centre

Since effective disaster mitigation and response requires not just a reliable response system, but also relevant education and research, there is a need for a centralised, dedicated regional disaster coordination centre. Such a centre should be located at a SEHA medical facility; the Abu Dhabi Ministry of the Interior and the Health Authority of Abu Dhabi should be tasked with its oversight.

Hospitals are ideally suited for coordinating such efforts as they are typically located near high-density population areas, have an existing infrastructure that includes communication assets and often house some of the responding agencies involved in disaster response on their premises. Moreover, the nearby Abu Dhabi airports could serve as receiving and distribution facilities for the regional disaster coordination centre should outside aid be required. The proposed centre could coordinate training in a cost-effective manner by avoiding duplication of training efforts and encouraging homogeneity across hospitals.

## Conclusion

This article reports on the process and results of facility-specific HVAs as the basis for an assessment of the disaster preparedness of Abu Dhabi's health care system. This project relied on—and promoted—close collaboration between the Disaster Medicine Section at Harvard Medical School and SEHA's health facilities; a standardisation of the HVA format and the research process; and the centralisation of leadership. The study offers potential benefits in other preparedness and response activities within SEHA and the UAE as a whole; for example, its findings could serve to inform the development of a regional emergency operation plan (EOP) with a focus on emergency management processes.

While carrying out HVAs in all public hospitals of Abu Dhabi was a valuable learning exercise, a number of limitations and gaps need to be highlighted and addressed for future HVAs. To begin with, the unfamiliarity of the project teams with the KP HVA tool may have led to some inaccuracy in the production of data. It should also be noted that some practitioners consider the KP HVA tool too subjective, suggesting another potential source of inaccuracy. In addition, even though the HVA team leaders at each hospital received similar instructions on the use of the KP HVA tool and on how to carry out the assessment, they may have had varying interpretations, which may have affected their approach to the study. Furthermore, there was limited direct exposure between reviewers and the facilities. Finally, the position and background of the HVA team leaders varied across different hospitals; for example, one was a medical director while another was a trauma team leader. These differences could have influenced the HVA assessment process since a surgeon, for example, may have placed emphasis on human hazards such as mass casualty incidents, while a public health professional may have stressed natural hazards, including epidemics. To enhance uniformity in HVA teams at different facilities, both the leaders and the team members should have similar backgrounds and positions (Campbell, Trockman and Walker, 2011).

Data collection is an essential part of the HVA process to evaluate the scope of risk and emergency preparedness; at the same time, accurate data is key to minimising the types of inconsistency noted in the data reviewed (see Observations 1 and 2). Future HVAs must therefore emphasise the need to gather complete and accurate information, such as from past events or hazards at a facility, to assist teams in their evaluation process. Potential sources of HVA data include academic institutions, disaster and emergency management centres, and meteorology and seismology agencies.

Participation from external community stakeholders—such as including police, fire fighters and emergency medical service providers—would have added significant value, given their experiences as first responders to disasters in the region (see Observation 6). The HVA tool and assessment should thus include a provision for input from external agencies regarding specific hazards in their respective domains. Their insight could help to highlight specific issues that might otherwise be overlooked. In addition, the external responders might usefully become more familiar with each other's technology and practices prior to an event.

Future objectives could include repeating the HVA process at regular intervals to build on experience, enhance familiarity with the tool and facilitate the adoption of more qualitative assessment tools to evaluate the impact of the aforementioned recommendations. At this writing, none of the hospitals had a separate budget or a time frame for future HVAs. A central coordinating committee should be established to coordinate and facilitate the HVA process. This particular aspect is likely to improve with time if each hospital develops an emergency management programme and a regional disaster coordination centre is established (see Observations 4 and 8). Benchmarking these measures with another assessment in few years would show what strides have been made in disaster preparedness in the UAE.

The partnership formed through this project between the Disaster Medicine Section at Harvard Medical School and SEHA highlights the importance of merging academic advancement and expertise with practical field application. Academic institutions, for their part, benefit considerably when operational agencies facilitate their access to the field. Greater collaboration and synergy between operational agencies and academic and training institutions should be encouraged.

This project can serve as an example of successful multidisciplinary emergency management processes based on the regionalisation concept. The development, implementation and maintenance of a long-term disaster preparedness approach enhance the ability of any health care system to anticipate disasters and to respond cooperatively and collectively when disasters strike. Such investment promises a significant strategic return and should thus become the foundation of a more robust national disaster health and medical response capacity.

As the first-ever HVA in UAE, and most likely in the Arabian Peninsula, this study was a landmark project. Indeed, SEHA has taken significant steps to incorporate the results of the assessment and recommendations into its recently developed emergency operation plan for the region. This follow-up involved the adoption of HVAs as fundamental steps in each facility's disaster planning process. In addition, each facility adopted an all-hazards approach and started developing a hospital incident command system and planning for hazmat capabilities. Moreover, the sector began work on a centralised disaster coordination centre to synchronise efforts across all relevant facilities. Such swift compliance reflects SEHA's motivation and enthusiasm for bringing its preparedness level to the highest international standards. Similar HVAs could be carried out in developing countries around the world to assess their levels of risk and to enhance emergency management in their health care networks.

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[2] See Berggren and Curiel (2006); Brevard et al. (2008); Broz et al. (2009); de Ville de Goyet (2007); Kleinpeter (2006); Peltz et al. (2006); and Rudowitz, Rowland and Shartzer (2006).

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