RESEARCH

Impact on Hospital Functions Following the 2010 Chilean Earthquake

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ABSTRACT

Objective: The objective of this study was to assess the impact of the 2010 Chilean earthquake on hospital functions and services. Hospitals functioning in a post-disaster environment must provide emergency medical care related to the event, in addition to providing standard community health services. This study focused on damage to both structural and nonstructural components, as well as to utility services.

Methods: Site visits were made to every hospital in a single province (Bio-Bio). Engineers conducted damage assessments while interviews of hospital administrators were conducted. The survey was requested by the Chilean Ministry of Health (MOH) to assess the impact of the earthquake on hospital operations and facility responses to those effects. Other important regional and hospital data were gathered from hospital administrators and the MOH.

Results: Seven government hospitals were surveyed. All hospitals in the region lost communications, municipal electrical power and water for several days. All reported some physical damage although only one suffered significant structural damage. All lost some functional capacity as a result of the earthquake. The loss of telephones and cellular service was identified as the most difficult problem by administrators. An average of 3 physical areas per hospital lost some degree of functional capacity following the earthquake.

Conclusion: Even in an earthquake-prone and very well-prepared country such as Chile hospital functions were widely disrupted by the event. The loss of hospital functions can occur even with minimal damage to the physical structure. The loss of communications can impede or halt response efforts at all levels. Hospitals should be prepared to self-sustain following a disaster for 2-3 days regardless of the level of structural damage. Understanding the details of these impacts is essential to hospital preparedness and plans for continuing services after a disaster.

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Key Words: Chile earthquake, disaster, hospital, functional capacity

Functioning hospitals are an essential component of disaster response after any type of event. They must not only provide emergency medical care related to the event but also continue to provide the health services necessary to maintain the health of the community they serve. The United Nations, through the World Health Organization, has made hospital risk and vulnerability reduction a cornerstone of international disaster preparedness for more than a decade through their "Safe Hospitals" initiative; the United States has also made it a priority to inform critical stakeholders of hospital seismic vulnerabilities and provide guidance on mitigation measures to improve hospital safety and functionality.[1] The focus of this initiative is to ensure the physical and functional capacities of hospitals after a disaster.[2,3] At the 2005 World Conference on Disaster Reduction in Kobe, Japan, the model of "safe and resilient hospitals" was identified as an integral component of community disaster risk reduction.[4,5]

Despite these initiatives, earthquakes have repeatedly severely disrupted hospital services. The Richter scale magnitude 7.0 earthquake that struck Haiti in January 2010 destroyed or severely damaged 22% of the hospitals in the entire country.[6] The 2005 Pakistan earthquake, measuring magnitude 7.6, closed 68% of the health facilities in the affected region.[7] In 2003, the 6.6 magnitude Bam earthquake in Iran reportedly destroyed almost all of the health facilities in the affected area, with the loss of almost 50% of the local health staff.[8] After the 2007 magnitude 7.9 earthquake in Peru, 60% of health facilities in the affected area reported some damage and 4 were destroyed, but 80% continued to provide services after the event.[9] The experience of continued functionality of a majority of health facilities in Peru is similar to what was observed after the 2010 Maule, Chile earthquake.

In the early morning hours of February 27, 2010, a magnitude 8.8 earthquake occurred off the coast of the Maule and Bio-Bio regions of Chile (Figure). This was the strongest earthquake in Chile since 1960 and 1 of the strongest ever recorded.[10] As of April 10, a total of 484 deaths resulted directly from the earthquake, 87 of which were reported from the Bio-Bio region.[11] A total of 117 hospitals are part of the Chilean health system that reside in the affected region of the earthquake; 23 (20%) of

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these hospitals suffered some degree of diminished operability as a direct result of earthquake damage.

As of 2001, the Chilean health system included 187 hospitals, 146 rural outpatient clinics, and 1102 rural health posts (without a permanent staff physician). Of the hospitals, 20 (11 855 beds) are high-complexity referral institutions, 30 are hospitals with several specialized departments (8019 beds), 23 are hospitals that offer several basic specialties (4114 beds); and 105 are operated by general practitioners (5332 beds).[12]

Conceptual frameworks for hospital preparedness have been developed in the United States[13]; however, attempts to quantify this capacity during an actual disaster have been limited due to the rapidly evolving nature of the events. The delivery of health care services by hospitals can be affected by a number of internal and external mechanisms following a disaster.[14] External effects come from the loss of municipal services such as power, telephones, water, and sewers. Internal mechanisms include structural damage, nonstructural damage, and damage to equipment and supplies. Services can also be diminished by the loss of personnel. This report focuses on the impact of the Maule earthquake on hospital functions and services, taking into consideration the external and internal mechanisms contributing to diminished functionality of hospitals in the Bio-Bio region of Chile.

METHODS

Research Team Formation

Three of the authors had initiated research preparations to explore the effects of earthquakes on health care systems before the onset of the February 27, 2010, earthquake in Chile. After agreeing to join the Earthquake Engineering Research Institute (EERI) effort to conduct an early reconnaissance trip to Chile, a senior EERI member and structural engineer was added to the team, along with an architect from the Chilean Ministry of Health, a geophysicist, and a Chilean structural engineering student.

Data Collection

Meetings were held with the Chilean Ministry of Health (MOH) upon arrival in the country to discuss their needs and goals for the assessment. The MOH selected the Bio-Bio province for the assessment, identified specific content areas for inclusion in the survey, and provided editing and translation assistance with the final survey instrument. They also assisted with the assessment by providing an official letter of authorization and staff to accompany the assessment team and conduct the interviews.

A multisection interview questionnaire was drafted and designed to capture qualitative and quantitative information on the effects of the earthquake on hospital operations and facility responses to those effects. Data were gathered from hospital administrators using a structured interview technique and directly from MOH statistics. A multidisciplinary team strategy was developed in which each hospital would be visited by a team that included structural engineers and health care and disaster specialists. The engineers conducted a damage assessment of the structural and nonstructural components and evaluated the operational capacity of the hospitals, and health care specialists interviewed the hospital administrator and chief medical officer of the hospital for information on the effects of the earthquake on hospital operations. The definition of "hospital" was based on the current Chilean MOH designation. There was not enough time to investigate smaller health care units during this rapid reconnaissance trip, and they were not included in the research plan.

After feedback from MOH personnel on the draft questionnaire, the form was translated into Spanish. The Bio-Bio region includes Chile's second largest city, Concepción, and runs inland to the Andes Mountains. Within the Region of Bio-Bio, we further focused on the Province of Bio-Bio, a jurisdictional subsection of the Region, with its seat in the city of Los Angeles. All of the hospital visits were arranged by MOH personnel and included at least 1 MOH employee, who usually participated in the damage inspections. The damage inspections followed US protocols that have been used in numerous countries. Our hospital visits took place between weeks 2 and 3 after the earthquake.

We pretested the draft hospital interview questionnaire at the Talca Regional Hospital by conducting the interview and inspection, after which we revised several aspects of the questionnaire. The questionnaire and inspection data were compiled on an Excel spreadsheet for initial review using basic descriptive statistics.

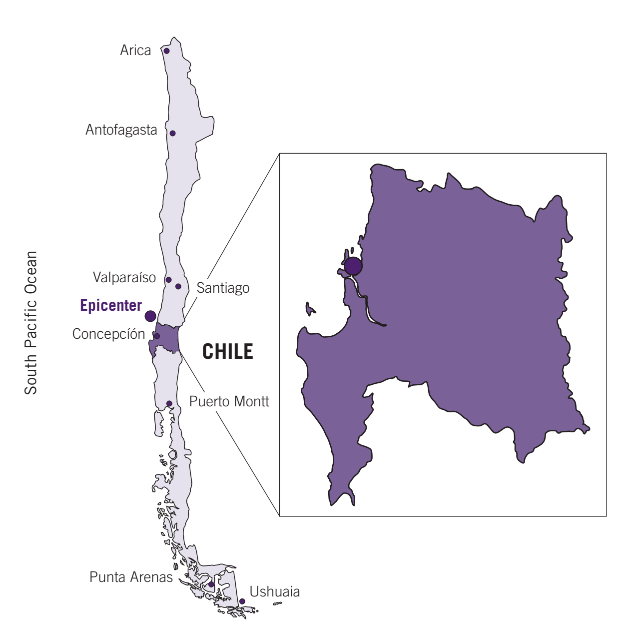
RESULTS

Description of Hospitals

Our study area, the Bio-Bio Province of Chile, has 7 government hospitals and 17 health centers (Table 1). There are no private hospitals in the province. The bed size of the hospitals range

FIGURE

Map of 2010 Chilean Earthquake



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from 26 to 433 (average 109), with the largest hospital (Victor Rios Ruiz) in the city of Los Angeles acting as the regional referral center.

The Los Angeles hospital is composed of 5 midrise buildings. The 3 newer structures are 4 to 6 stories tall, were built between 2000 and 2005, and are concrete frame with shear walls and masonry infill walls. The 2 older buildings of the Los Angeles Hospital, built between 1950 and 1970, are 3 stories tall and are constructed of concrete and masonry brick. The Mulchen hospital is a 2-story, concrete-frame building constructed in the shape of an "H." The hospital in Laja has a steel-frame main structure and an auditorium that are each single story and built in the 1960s; the hospital also has a 2-story administrative building, erected in 1998, that is also steel frame with masonry infill walls. The remaining 4 hospitals—Yumbel, Naciminento, Santa Barbara, and Huepil—are single-story concrete-frame buildings built after the 1960 Chilean earthquake (magnitude 9.5, the largest on record), between 1967 and 2005.

There are more than 100 hospitals in the provinces affected by the earthquake (Valparaiso, O'Higgins, Maule, Bio-Bio, Araucania, and Metropolitana). After the earthquake, the Chilean MOH found 4 of these hospitals to be uninhabitable, 12 to have >75% loss of function, and 8 to have <75% loss of function and only partially operational.[15] Only 1 hospital in our study area, Victor Rios Ruiz, of Los Angeles, was on the list of partially operating (<75% loss of function) hospitals; all of the others were considered fully functional at the time of our assessment.

Structural Damage

The 5 smallest hospitals—4 concrete frame, 1 steel frame—that are single story did not incur any structural damage. The second largest hospital that is concrete frame and 2 stories tall had minor visible concrete cracking. The only hospital that suffered structural damage is Victor Rios Ruiz of Los Angeles. One of the buildings at Los Angeles, built in 2000, suffered severe racking of its penthouse due to torsion; this building also had buckled steel roof trusses. Two other buildings at Victor Ruiz, circa 2005, suffered damage to some of their columns as well and had slight cracking on the shear walls.

Utilities Damage

Although structural damage was minimal or nonexistent in the hospitals of our study region, most suffered some nonstructural damage. The most notable nonstructural damage in all of the hospitals was the loss of utilities immediately after the earthquake. All 7 hospitals in the region lost municipal electrical power for several days, and several had arranged local priority for fuel delivery for their backup generators. Although all of the hospitals had backup power supplies, 43% of them reported some difficulty with their systems, ranging from inability to start the system for almost 1 hour to having insufficient power to maintain critical services such as radiology. One generator in the hospital at Los Angeles failed entirely, but fortunately there were 2 other functioning generators on site that were part of an ongoing construction project. A second hospital reported difficulty with its generator's automatic startup; personnel were only able to manually start it more than 30 minutes after the earthquake occurred.

Although every single hospital was equipped with backup power supplies, such redundancy was not present in their communication systems. External communications (land line and cellular telephones) were disrupted for all of the facilities for between 3 and 7 days. This disruption created enormous difficulties in coordinating aid and for requesting outside help. As 1 hospital administrator reported, "It was like we were an island, there was no way to get help." This problem was exacerbated further by the nationally centralized management of hospitals, with limited regional and individual autonomy and control.

Five hospitals (71%) lost their municipal water supplies. All of these hospitals had underground tanks, roof tanks, or both available with their backup water supply. Some hospitals, however, reported problems with their backup water system. One hospital was unable to circulate the backup water at all. Another hospital had a broken water pump and thus did not have access to its backup immediately; however, staff members were able to replace it with a boiler pump and successfully distributed water from their underground tank.

TABLE 1

Hospitals in Bio-Bio Province, Chile, 2010

	Hospital 1 Yumbel	Hospital 2 Nacimiento	Hospital 3 St Barbara	Hospital 4 Laja	Hospital 5 Mulchen	Hospital 6 Huepil	Hospital 7 Los Angeles
No. beds	53	57	39	50	179	26	433
ED visits, annual	22 000	54 000	28 000	40 570	48 000	22 000	158 000
Discharges, annual	2500	9100	1311	2617	6400	1300	17 800
No. physicians	7	8	6	8	13	6	265*
No. nurses	6	7	4	6	8	4	155**

ED, emergency department.
*A total of 61 of these are on-site.
**A total of 42 of these are on-site.

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Nonstructural Damage

Some of the hospitals in our study region suffered damage to mechanical, electrical, plumbing, and medical equipment and to other nonstructural components and contents that were not properly anchored or braced. Four hospitals reported damage to and collapse of their suspended ceilings. Cracking of the plaster over their brick walls and partition damage were also common. A few hospitals also experienced damage to their pipes and 2 suffered moderate water damage because of pipe failures, 1 of which lost the function of 2 operating rooms. One hospital reported several overturned oxygen tanks that were not anchored properly before the earthquake, a broken maternity incubator caused by the shaking, and a fallen wall-mounted television. In addition, all of the elevators in the hospital in Los Angeles were damaged and rooftop equipment jumped off vibration isolators.

Affected Areas

All of the hospitals suffered some physical damage (Table 2). One hospital (Huepil) incurred only cracked windows, therefore, no services were affected. The radiology department and the laboratory were the most commonly affected areas because of the combination of the loss of municipal electrical power with damage to either the building or their sensitive equipment. More than 25% of the hospitals reported earthquake impact damage in their operating rooms, outpatient clinics, kitchen, laundry, and their administration.

Functional Impact

All of the hospitals reported losing some intrafacility functional capacities as a result of the earthquake. Although no hospital lost the capacity to provide all services, all but 1 experienced reductions in multiple services for up to 7 days (Table 3). Because of the loss of power, radiology services were the most commonly affected; this occurred in 6 of the 7 hospitals we surveyed. Laboratory services were also affected in 3 of the 5 hospitals, due largely to the loss of supplies and equipment. The hospital in Huepil underwent only cosmetic damages, but they lost the critical services of radiology (plain radiographs) and the laboratory. Radiology did not work because the backup generator was not sufficient to power the equipment. The laboratory did not function because the highest-trained laboratory technician did not report to work for 3 days due to damage to his house and injuries in his family.

In terms of patient care capacity, the largest deficit was due to the loss of patient care beds in the Los Angeles hospital, which was reduced from 433 to 200 beds because of the necessity to close portions of the hospital. The older building at the Los Angeles Hospital complex suffered water damage due to broken water pipes. The closure of this building for repairs reduced the total bed count by 70, seriously affecting their surgical ward.

Regarding nonclinical services in the hospitals we surveyed, the most frequent interruption was due to the loss of patient medical record organization, resulting from collapsed and tipped-over file management systems. No hospital had electronic files to back up all of the paper-based records. The records were not lost, but it took from 1 to 7 days to reorganize the files sufficiently to make them usable. Food preparation and laundry services were a problem in 2 of the 7 hospitals.

In summary (Table 4), although none of the surveyed hospitals suffered catastrophic collapse or any directly-related fatalities, there was sufficient structural and nonstructural damage to significantly impair patient care. (The hospital in Los Angeles reported 2 patient deaths due to cardiac arrest during the first 2 hours postearthquake. It could not be determined whether these deaths were in any way related to the event or were unrelated events due to preexisting pathology.) Externally supplied support functions (eg, water, electricity, communications) were the most common failures.

DISCUSSION

The provision of hospital-based health care requires a finely balanced and coordinated series of inputs within a structure that

TABLE 2

Physical Areas Affected by Service Type, Bio-Bio Province, Chile, 2010

Unit	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Total (%)
Inpatient wards	N	N	N	Y	Y	N	Y	3/7 (43)
Operating rooms	NA	NA	N	N	NA	N	Y	1/4 (25)
Laboratory	N	Y	N	Y	N	N	Y	3/7 (43)
Radiology	Y	Y	N	Y	N	N	Y	4/7 (57
Emergency department	N	N	N	N	N	N	N	0/7 (0)
Outpatient clinics	N	N	N	N	Y	N	Y	2/7 (28)
Psychiatry	NA	NA	N	N	NA	N	NA	0/3 (0)
Blood bank	NA	NA	N	NA	NA	N	N	0/3 (0)
Kitchen	N	N	N	Y	N	N	Y	2/7 (28)
Laundry	N	N	N	N	Y	N	Y	2/7 (28
Administration	N	Y	N	Y	N	N	N	2/7 (28)
Morgue	N	N	N	NA	N	N	Y	1/6 (17)
Total units losing function	1	3	0	5	3	0	8	

N, no; NA, not applicable/service not provided; Y, yes.

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houses and supports the required functions. Although some disaster types are more likely to affect a limited list of inputs, earthquakes can directly or indirectly affect a broad spectrum of them. Beyond the potential for damage to the structure itself, earthquakes, through the damage done to transport, communications, water, and power supply systems, can significantly impede the lifelines that keep hospitals operating. In addition, as is the case in some other kinds of disasters, earthquakes have the potential for limiting the number of hospital personnel available to keep the hospital operational, through direct injuries or deaths to personnel, or the need for personnel to attend to their families. Although all of this is easily described conceptually and is derived from practical experience, a paucity of research critically examines the exact impediments to continued hospital functioning in the crucial days following a rapid-onset disaster.

TABLE 3

Number of Days Services Lost or Reduced, Bio-Bio Province, Chile, 2010

Service	Hospital 1 Yumbel	Hospital 2 Nacimiento	Hospital 3 St Barbara	Hospital 4 Laja	Hospital 5 Mulchen	Hospital 6 Huepil	Hospital 7 Los Angeles
Inpatient services							
Inpatient wards	>7 d	1-3	Normal	<1 d	Normal	Normal	4-7 d
Surgical	NA	NA	Normal	NA	NA	NA	4-7
Obstretics-gynecology	Normal	Normal	Normal	Normal	Normal	Normal	1-3
Pediatric	>7 d	Normal	Normal	Normal	Normal	Normal	1-3 d
Psychiatric	NA	NA	Normal	Normal	NA	NA	NA
Dialysis	NA	NA	Normal	NA	NA	NA	>14 d
Outpatient services							
Emergency department	>7 d	Normal	Normal	Normal	Normal	—	1-3 d
Outpatient clinics	4-7 d	Normal	Normal	<1 d	Normal	Normal	>7 d
Psychiatry	NA	NA	Normal	Normal	NA	Normal	NA
Rehabilitation	4-7 d	Normal	Normal	3-7 d	NA	Normal	NA
Support services							
Plain radiographs	1-3 d	1-3 d	Normal	3-7d	1 d	4-7 d	4-7 d
Computed tomography	NA	NA	NA	NA	NA	NA	1-3 d
Ultrasound	Normal	1-3 d	NA	NA	Normal	Normal	1-3 d
Laboratory	Normal	1-3 d	1-3 d	<1 d	Normal	4-7 d	7 d
Blood bank	NA	NA	NA	NA	NA	Normal	Normal
Sterilization	Normal	Normal	Normal	1-3 d	Normal	4-7 d	>7 d
Nonclinical services							
Adminstration	Normal	2 d	Normal	Normal	Normal	Normal	Normal
Medical records	Normal	1-3 d	Normal	3-7 d	Normal	Normal	1-3 d
Food preparation	Normal	Normal	Normal	5 d	Normal	Normal	1-3 d
Laundry services	Normal	Normal	Normal	Normal	3 d	Normal	4-7 d

NA, not applicable/service not provided.

TABLE 4

Summary of Functional Loss by Hospital

Function	Hospital 1	Hospital 2	Hospital 3	Hospital 4	Hospital 5	Hospital 6	Hospital 7	Total (%)
External								
Electricity	Y-P	Y	Y-T	Y-T	Y-T	Y-P	Y-T	7/7 (100)
Backup electric	Y	Y	Y	N	N	N	Y	3/7 (43)
Water	Y-P	Y-P	N	N	Y-T	Y-T	Y-P	5/7 (71)
Sewer	N	N	N	N	N	N	N	0/7 (0)
Telephones	Y	Y	Y	Y	Y	Y	Y	7/7 (100)
Internal								
Sterilization	N	N	N	Y	N	N	Y	1/7 (14)
Computers	N	N	N	N	N	N	Y-T	1/7 (14)
Medical gases	N	N	N	N	N	Y	N	1/7 (14)
Suction	N	N	N	N	N	N	N	0/7 (0)
Total services lost	4	4	3	3	3	4	6	

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Despite the important role of hospitals in disaster response there have been relatively few studies that assess the impact on or functioning of hospitals after a disaster event. Much of the literature is either old or anecdotal reviews or case reports. Some of the earliest descriptions of an earthquake's impact on hospital services resulted from the 1989 Loma Prieta earthquake in California, when hospitals lost power and water and specific services such as radiology.[16,17] Following the Kobe, Japan earthquake in 1995 reports indicate that at least 4 hospitals were immediately closed and 12 were severely damaged; other hospitals reported losing services such as operating rooms, sterilization, and radiology.[18,19] After the 2005 Taiwan earthquake, 1 study included a brief discussion of the impact of hospital services but with limited detail beyond general structural damage.[20] The lack of literature in this study area indicates that more research is necessary to identify the exact mechanisms that disrupt hospitals from providing regular services after a disaster.[21]

Some specific functional affects have been studied. For example, in 2003, an electrical blackout affected 8 US states and parts of Canada. Hospital functions such as ventilation, electrical generators, elevators, and computers were affected.[22] Another study following the 2007 Peruvian earthquake documented the general loss of health facilities, but did not describe in detail the services/functions that were affected.[9] There have also been simulation models developed to attempt to predict the impact on hospitals and their hospital capacities following earthquakes.[23] Although this may be useful to influence planning, models are most robust when based on studies validated using prior events.

This study demonstrates serious effects on hospitals' functional capacities despite limited structural damage. Understanding the details of these affects is essential to hospital preparedness and plans for continuing services after a disaster. These details are also essential to the development of models that estimate building operability in future seismic events and help inform design choices of building components.[24]

Our findings in this study can be summarized in the following observations:

1. There is great value in mitigation through antiseismic building design. Despite the extreme amount of energy released in the February 27, 2010, Chilean earthquake, the value of Chile's strong adherence to strict building codes was demonstrated in the fact that none of the affected hospitals experienced a complete collapse nor sustained life-threatening damage. Such has not been the case in major earthquakes in Mexico, Nicaragua, El Salvador, and, most recently, Haiti.
2. Loss of hospital functions occurs even with minimal damage to the structure. In the present study we found that both nonstructural damage and utility services failures had the potential to cripple hospital functions. The loss of external power and water supplies, for example, can force hospital evacuation if they cannot be remedied.
3. Loss of communications was the most common problem identified by hospital leadership. This prevented any kind of coordinated response, even within the region. Emergency managers are acutely aware of the high priority of maintaining robust and redundant means of communications for emergencies, but this problem continues to recur. We presume that the Chilean health care system is not unique in this way.
4. Disaster preparedness and disaster planning are not always the same thing. The hospitals we examined demonstrated the value of preparedness through their reserve water supplies (not a common feature in US hospitals), backup generators, and formation of hospital disaster committees. Few claimed to have plans for emergency operations, however, but all of them said that they used their disaster committees to help make decisions and guide operations during the emergency period.
5. Because of the loss of communications and transportation disruptions, hospitals were forced to be self-sustaining for a minimum of 48 hours.
6. Decision making was challenging because the management of the health care system in Chile is centralized in Santiago; regional autonomy is limited and most major decisions are approved in the capital. Due to the loss of communication, hospital directors found themselves in the uncomfortable position of making decisions without the accustomed support or guidance from Santiago, and were unsure of their authority to make decisions regarding resource allocation.

The importance of conducting this kind of research in multiple settings is clear. Hospitals are critical structures and must remain functional after any type of disaster. Loss of hospital functions prevents the treatment of emergencies, chronic illnesses, and even public health functions such as immunizations and prenatal care.[25] After an earthquake, hospital services are particularly important because of the high number of injuries caused by these events and because patients who need continuing care for chronic diseases may not be able to find these services in their normal outpatient care facilities. The Chilean MOH has expressed significant interest in formalizing this process and conducting further assessments in areas that were more extensively damaged following the February 2010 earthquake.

Even in an earthquake-prone and extremely well-prepared country such as Chile, hospital functions were widely disrupted by the event. Major improvements can be made to make hospitals in Chile (or anywhere) more earthquake resilient; these improvements include securing equipment and supplies, regularly maintaining emergency backup systems, and developing hospital-specific disaster plans that can help minimize the amount of on-the-spot decision making that must occur. This model of multidisciplinary assessment teams can be adapted to damage and function assessment after any type of disaster. Further assessments should be conducted to validate this method as a possible standard approach to postdisaster assessment.

Limitations

The primary limitation of this study is that not all of the affected facilities in the country were assessed and the specific sites that were surveyed were not chosen randomly. The sites

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surveyed were, however, a complete sampling of all of the facilities in a single region in a heavily affected area of the country and were assessed at the request of the MOH.

Another limitation is inherent to all disaster research, in which the need to assess must always be balanced against the need to respond, while from the researcher's perspective the availability of data are time sensitive. Our method and tool were developed theoretically before the event but could not be finalized until the actual response. The study method was pretested at a single facility in Talca and the questionnaire was refined; there are improvements we would make in the questionnaire now. We are unsure, however, to what degree these improvements would fortify the strength of our findings. The structural damage assessment methodology implemented in Chile is based on protocols that have been used in the United States for more than 2 decades.

Another limitation is the paucity of other similar hospital-impact studies using both engineering and health services research approaches. This lack of similar work limits our ability to engage, at this stage, in the research steps of theory formation and testing. We are restricted to descriptive research with limited analytical capability. In the coming years, we hope to contribute to the ability to use comparative studies in the process of theory formation.

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