RESILIENCE RECONAISSANCE FOR HOSPITALS AFTER THE 2010 MAULE EARTHQUAKE

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ABSTRACT

Major earthquake disaster causes disruption in the functioning of a society and may lead to significant infrastructure losses. Healthcare infrastructure is very critical to handle earthquake emergency. Hospitals are essential facilities required to remain operational and maintain communication with other agencies and hospitals. The interdependencies between trauma centers, general hospitals, emergency care, and medical supply warehouses are very critical in case of emergency. On Saturday, February 27, 2010, Chile was struck by a major earthquake (M\textsubscript{w} 8.8) that affected 13 million people, approximately 80\% of the population. Some studies evaluated the Chilean healthcare system efficiency following the 2010 earthquake; however, little research attention was paid to evaluate the resilience/recovery of healthcare services a few years following the 2010 earthquake. This paper investigates the current level of resilience/recovery of a segment of the Chilean healthcare system and the challenges to recovery and rebuilding processes seven years following the 2010 earthquake. To this end, field hospital resilience assessment was performed along with community healthcare system public confidence field surveys in several Chilean cities such as Santiago, Viña del Mar, Santa Cruz, Lolol and Talca. The mitigation measures following the 2010 earthquake were observed and documented and their efficiency tested for Iquique 2014 and Illapel 2015 earthquakes was evaluated.

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Resilience Reconnaissance for Hospitals after the 2010 Maule Earthquake

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ABSTRACT

Major earthquake disaster causes disruption in the functioning of a society and may lead to significant infrastructure losses. Healthcare infrastructure is very critical to handle earthquake emergency. Hospitals are essential facilities required to remain operational and maintain communication with other agencies and hospitals. The interdependencies between trauma centers, general hospitals, emergency care, and medical supply warehouses are very critical in case of emergency. On Saturday, February 27, 2010, Chile was struck by a major earthquake (Mw 8.8) that affected 13 million people, approximately 80% of the population. Some studies evaluated the Chilean healthcare system efficiency following the 2010 earthquake; however, little research attention was paid to evaluate the resilience/recovery of healthcare services a few years following the 2010 earthquake. This paper investigates the current level of resilience/recovery of a segment of the Chilean healthcare system and the challenges to recovery and rebuilding processes seven years following the 2010 earthquake. To this end, field hospital resilience assessment was performed along with community healthcare system public confidence field surveys in several Chilean cities such as Santiago, Viña del Mar, Santa Cruz, Lolol and Talca. The mitigation measures following the 2010 earthquake were observed and documented and their efficiency tested for Iquique 2014 and Illapel 2015 earthquakes was evaluated.

Introduction

A disaster is a serious disruption in the functioning of a community or society that causes a large number of deaths as well as material, economic and environmental losses and impacts that exceed the capacity of the affected community or society to deal with the situation through the use of their own resources [1]. Hospitals play an important role in the aftermath of any emergency event [2]. On Saturday, February 27, 2010, Chile was surprised by an earthquake that

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reached a moment magnitude of 8.8 [3], which affected 13 million people, or approximately 80% of the population. Evaluation of how hospitals operated after the earthquake and subsequent tsunami of February 27, 2010, is crucial to understand its role in serving the people in the time of disaster and it’s learning of the healthcare infrastructure to respond to emergency in future.

**Description of the Previous Damage and Scope of Study**

The Chilean healthcare system is composed of four major parts:
- Public and private health care system
- Ministry of health’s public health and medical care networks
- Public medical care network
- Pre-hospital assistance, urgent service of ambulances (SAU) for Santiago, onsite urgent care medical assistant of high complexity (SAMU)

The third component consists of four types:
- All specialties
- Some specialties
- No specialties
- Family medicine.

In terms of damages, 135 hospitals distributed between regions V and IX received the impact of the earthquake. In the initial evaluation, 51 hospitals continued to function without major problems, 17 were completely disabled, 62 of them suffered severe damage and 5 health care facilities were classified as structural damage: Talca, Curicó, Hualañé, Constitución and Parral. During the immediate emergency, 19 field hospitals were installed in 4 of the 5 hospitals that suffered major structural damage. In addition, 4,249 beds were lost from a total of 19,439 existing (22%), which is considered a great non-structural damage (Reconstrucción red Hospitalaria, Ministerio de Salud). Of the beds in public hospitals, 18% continued to be out of service one month after the earthquake.

In term of nonstructural damage, the 80% corresponds to elevators (> 75% non-functional), equipment anchorage, equipment on wheels, suspended ceilings (one instance of packing tape mitigated loss), etc.

Given this widespread damage of healthcare delivery facilities, a multi-section 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 [2]. A study area in the Biobio Region was chosen to assess the impact on a regional hospital system. The study area included seven public hospitals, seventeen health centers, and no private hospitals. The damage observed to structural, non-structural, and mechanical, electrical, and plumbing systems by the reconnaissance team in the hospitals of the study are described in detail elsewhere [2]. All hospitals suffered some physical damage, though all but one saw reductions in multiple services for up to a week. More than a quarter of the hospitals reported impact to their operating rooms, outpatient clinics, kitchen, laundry, and their administration due to earthquake damage. In terms of clinical services, the main regional hospital suffered more than a 50% reduction in bed count. The most frequent interruption of non-clinical services was due to the loss of patient medical record organization. The records were not backed up electronically, and took from a day to a week to restore the paper files. Food preparation and laundry services were a problem in two of the seven hospitals.

The lessons learned in the hospital emergency planning is the lack of training and that the
centralized emergency planning was ineffective.

Regarding the scope of study the current paper seeks to evaluate the functioning of hospitals during the earthquake emergency and also the current state of the health system, 7 years after the event, in the cities/towns of Santiago, Viña del Mar, Santa Cruz, Lolol and Talca. The main objective is then to evaluate the recovery/response of the health system to the state of catastrophe generated. The methodology to carry out the evaluation consists of interviews with local residents from each city and also state officials.

**Methods of Data Collection**

The resilience reconnaissance travel study program by EERI in collaboration with CIGIDEN is aimed at qualitatively assess the state of infrastructure after seven years of 2010 earthquake event. Also, to understand the massive recovery process carried out post 2010 event. As a part of the program, many sites were visited to see the damaged sites, relocated communities and newly built infrastructure. The data collected at these sites can broadly be classified into two parts:

1. Geotagged Photographs
2. Information from various stakeholders through personal interaction

The geotagged photographs have the information of the location of the photograph taken in terms of the latitude and longitude. The geotagged photograph will give an idea of the state of the infrastructure and analyze the progress in a retrospective manner.

The travel study program gave opportunity to meet different stakeholders of the society including professionals involved in the recovery process, researchers working towards better technology for seismic safety, people from local administration and most importantly people who suffered damage and relocated to other places. Multiple interviews with all of them were carried out to reap information to understand the recovery and relocation process, and their preparedness going forward to face similar large earthquakes.

**Assessment Results**

Observations from the resilience study can be classified into three categories: (1) damage and service interruption, (2) recovery and resilience and (3) hospital evacuation procedures. Damage and service interruption highlights the recollection of hospital staff on the damage observed during the Maule earthquake in 2010. Recovery and resilience documents the changes made to improve resilience in the medical community and the current satisfaction communities have with their local medical facilities. Finally, hospital evacuation procedures documents previous and new methods of evacuating patients during and after an extreme event.

**Damage and Service Interruption**

While there are no documented cases of hospital collapse or directly-related fatalities, there were observations of significant damage in medical facilities that directly impaired patient care (Llera et al. [4]). A detailed survey of the structural and nonstructural damage in hospitals after the 2010 earthquake can be found in Mitani-Reiser et al. [2]. This paper will tackle in more details
the recollection of the damage from hospital staff at the Universidad Católica San Carlos de Aponquindo clinic in Santiago, Chile (Fig. 1).

Figure 1. The Universidad Católica San Carlos de Aponquindo clinic.

The UC San Carlos de Aponquindo clinic is an example of one of the isolated buildings that behaved extremely well during the 2010 earthquake. Half of the hospital was isolated above the basement level in 2005 (Fig. 2). The other half remained fixed. An interview was conducted with the head of the nursing staff, security officer and two medical doctors at the hospital to document the observed damage after the 2010 earthquake.

Figure 2. a) Pedestrian bridge connecting fixed as isolated buildings; b) Gap of 25 [cm] where isolated building moves.

The earthquake occurred at night, so there were not many people in the building. The isolated building was completely undamaged. However, nonstructural damage was observed in the fixed building, primarily in the maternity ward. This damage consisted of fallen patient records, some minor cracks, and fallen ceiling tiles. Of the observed damage, the reorganization of patient medical records was the most frequent source of service interruption in hospitals after the 2010
earthquake. The building was operational within the same day.

This damage was corroborated by interviews with two medical doctors in the hospital, one between 35 to 40 years old and the other between 60 and 65 years old. While hospital functionality was nearly normal after the earthquake, the head of nursing staff and one of the doctors indicated that there was a shortage of personnel available to take care of patients directly following the earthquake.

Recovery and Resilience

A number of new requirements have been implemented by Chilean codes to preserve the functionality of hospitals after a severe seismic event (Fig. 3). The success of base isolated hospitals during the 2010 Maule earthquake has prompted the Chilean Ministry of Public Health to require base-isolation for public hospitals. Note, however, that this requirement has not been extended to private hospital facilities. In 2010, thirteen base isolated structures were exposed to the earthquake, including four seismically isolated healthcare facilities [4]. In 2015, more than 80 structures in Chile are base isolated.

Figure 3. a) Evacuation sign; b) Safety leader uniform.

Despite this relatively progressive policy, a number of interviews in local communities indicated dissatisfaction with local healthcare facilities. Two hospitals, one in Viña del Mar and one in Constitución, were observed to be in tsunami inundation zones. Several interviews are documented from three different communities.

Santa Cruz

Four interviews were conducted at a public housing complex outside Santa Cruz. The houses built in this complex were constructed on base isolators. While there were not many casualties after the earthquake, the healthcare clinic near the community was reported to be damaged. A new, small clinic was constructed near the community in 2010. However, severe medical cases are fed to the hospital in Santa Cruz.

An interview of a male of about 40 described the local hospitals as under-served. He gave a relatively high rating to the local healthcare facilities before the earthquake, but implied that the nearby healthcare facilities could not support the surrounding community following the
earthquake. The small facilities that are available appear to be very good and well-served by a number of international healthcare professionals. But these small facilities tend to be understaffed. Another interview of a male between 25 and 35 confirmed these statements.

In contrast, an interview with a male government official of about 45 indicated greater confidence in the local healthcare system. He felt the hospitals had training for disasters and evacuation procedures. This appeared to be in inconsistent with the two interviews of social housing residents.

Constitución

A number of interviews were also conducted at the social housing complex in Constitución, a city that was devastated by a tsunami following the 2010 earthquake. The local hospital was damaged following the earthquake. The current hospital was located in the tsunami inundation zone, and three other local medical clinics currently served the area. Constitución is the location of a number of progressive social dwellings designed by Alejandro Aravena. These houses were split into two phases. The first phase allowed half the home to be built within reasonable cost. The second phase of the housing could then be personalized and built by the homeowners in at a later time. In response to the devastation of the tsunami, these housing complexes were located on a hill, far away from the original housing sites.

In general, interviews with people in this new community indicated discontent with hospital service. A number of residents were asked about their confidence in the local healthcare facilities. Of the five people interviewed, four indicated that the new hospitals were too far away and had much longer waiting times. In contrast, the fifth interview indicated that the new hospital facilities were much better than the ones before the earthquake. An interview with a local woman of about 40, indicated that she was very satisfied with her new home. However, she was dissatisfied with the relocation of the housing community after the tsunami. She had to travel to Talca, a city outside Constitución, for specialized healthcare.

Another interview with a family couple with two children supported many of her statements. The man had to buy a car because there was no bus to the downtown area. He also reiterated that the current hospital didn’t work very well, and that the local medical facilities were very far away, making it difficult to take the children for frequent checkups. The man also indicated that ambulances don’t come to the relatively isolated community except for extreme situations. However, despite these concerns, he also indicated that there were plans to build a new public facility closer to the community.

Talca

Per a conversation with a structural engineer in Santiago, it was felt by many professionals that the general public did not know about the change in code to isolate new public hospitals or whether that indicates a structural upgrade. Another interview with a professor at the Universidad de Talca indicated that he felt the new hospitals were better and had significantly better care and medical equipment. This may indicate that the dissatisfaction reported by other members of the community may be less with the medical care, and more with relocation and an under-staffing problem causing longer wait times. These observations may also indicate that the dissatisfaction felt by the community has to do more with a lack of public communication about newly implemented safety policies that have not addressed the disenchantment of the local
Evacuation Procedure

In a survey conducted in [2] almost all of the hospitals surveyed had to perform patient evacuation following the 2010 earthquake. In the hospitals surveyed for this report, hospital staff reported the implementation of new training protocols for evacuation procedures following an extreme event.

Description of evacuation procedures

A conversation with an emergency care doctor in Viña del Mar regarding the tsunami evacuation process [5] carried out inside a hospital in the inundation zone provided some insight into the procedure. In this particular hospital, the evacuation process is a vertical evacuation. Patients that are able to walk take the stairway to higher floors. Other patients are taken care of by the doctors and medical staff employees. The evacuation process is carried out to the second floor once the alarm starts. It is carried out to the third floor if the alarm continues. The hospital has evacuated patients during alerts after the 2014 and 2015 earthquakes. The doctor explained that the process was quite successful and without any significant losses. The employees and staffs are also trained with the safety protocols before they join the hospitals.

A detailed interview with the head of nursing staff and the security officer at the Hospital Militar reported similar evacuation protocols in the event of an earthquake. Prior to the 2010 Maule earthquake, there was an evacuation protocol, but this protocol was not written down and was unclear. While an evacuation did occur, the protocol has since been updated to improve the evacuation process. This new protocol is now written down and is the official protocol of the hospital. The protocol is hierarchal, and nursing staff are designated as emergency leaders. A vest, whistle, and pen to mark doors where patients cannot be immediately evacuated are provided in a cabinet for those emergency leaders. The other staff directly follows the directions given by these leaders. Patients are informed of the danger and divided into different capacities based on their medical condition. Concurrent interviews of medical doctors inside the hospital corroborated this description. While one of the two doctors interviewed did not know the exact evacuation procedure, he did know that he was supposed to follow and cooperate with an emergency leader. Both of the doctors interviewed felt that the hospital staff is now more aware, trained, and prepared to respond to a future disaster.

One significant detail differed between the interview with the doctor in Viña del Mar and the interview with the security officer in Santiago. As part of the evacuation procedure, the doctors were supposed to evacuate after an earthquake to protect themselves as valuable resources. This was in response to the lack of hospital staff following the event in 2010. However, the doctor interviewed in Viña del Mar stated that he would protect his patients with his own body as part of his Hippocratic Oath. This appears to be in contradiction with the evacuation procedures already in place and may cause some disorder following a future earthquake.
Loss of Communication

One of the key issues that were documented in the evacuation strategies during the 2010 earthquake was a breakdown in telephone communication [2]. The transfer of patients between facilities was often a critical aspect of distributing the demand for care across the available hospitals. However, this system was rendered relatively unstable by the loss of communication between medical centers.

At both hospitals were staff was interviewed, the evacuation protocol depends on communication with COE, the Operative Center of Emergencies. The state of the hospital is reported to COE in the case of holidays or large events to indicate whether they have more patients than usual. The COE then assigns patients a hospital or clinic location in case of an earthquake, fire, or massive accident (> 40 people injured). While this communication tends to depend on a wireless network, both of the hospitals indicated that the ambulance radio would be used in the case of disabled communication. However, there does not seem to be an official network that comes into effect if communications are no longer functional.

Recommendations and Conclusions

The requirement that public hospitals be base isolated is a very progressive undertaking by the Chilean government. However, there appears to be a gap between the policies being implemented to improve the safety and occupancy of healthcare facilities and the public understanding of these improvements. A number of interviews showed dissatisfaction of the local communities with their healthcare systems. However, this may be due to under-staffing rather than a lack of facilities. In many cases, residents have commented that the facilities have been upgraded and that the healthcare is quite good, it is just located inconveniently far or is under-staffed. This and contradictory statements made by groups more informed about new earthquake policies make the condition of these services unclear. It is also unclear whether the opinion of the local communities on the services of the hospitals has to do with poor performance of the hospitals directly following the 2010 Maule earthquake.

Despite improvements in the evacuation protocols of the two hospitals interviewed, there is no clear indication that a robust network is in place for hospitals to communicate following a future disaster. This is especially crucial since the re-distribution and movement of patients following an earthquake requires a network of hospitals, clinics, and medical centers. While there is a hierarchical organization underlying the evacuation protocol, it is unclear how well neighboring hospitals can communicate with landline, wireless, and cellular services are interrupted.

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