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# INVESTIGATING COMMUNITY RESILIENCE IN NEPAL: A HEALTHCARE FOCUS

J. Mitrani-Reiser[(1)], M. Mieler[(2)], H. Kumar[(3)], S. Shrestha[(4)], Michael Germaraad[(5)], K. O'Conor[(6)], T.D. Kirsch[(7)]

[(1)] *Assistant Professor of Civil Engineering, Johns Hopkins University (JHU), jmitrani@jhu.edu*
[(2)] *Adjunct Assistant Research Engineer of Civil Engineering, Johns Hopkins University (JHU), mmieler@jhu.edu*
[(3)] *Regional Coordinator for South Asia, GeoHazards International (GHI), hari@geohaz.org*
[(4)] *Deputy Executive Director, National Society for Earthquake Technology-Nepal (NSET), shresthasn@gmail.com*
[(5)] *Resilience Planner, Association of Bay Area Governments (ABAG), MichaelG@abag.ca.gov*
[(6)] *Medical Student, Johns Hopkins University (JHU), koconor1@jhmi.edu*
[(7)] *Associate Professor of Emergency Medicine, Johns Hopkins University (JHU), tkirsch1@jhmi.edu*

## Abstract

Following the M7.8 earthquake on April 25, 2015 in Nepal, an international research team of several academic and practitioner experts in earthquake engineering, disaster management, and medicine spent two weeks (spread over one year) in Nepal documenting its impact. This paper uses multidisciplinary reconnaissance observations collected roughly one month (EERI/NSET reconnaissance team) after the earthquake and then again one year (PEER/EERI reconnaissance team) after the earthquake to assess community impact and recovery, with a specific focus on the health care sector.

The timing of the earthquake (i.e., at noon on a Saturday) helped minimize the casualties of the disaster, but even so, nearly 9,000 people lost their lives and more than 22,000 were injured due to the earthquake. The World Health Organization's Global Health Cluster Report indicates that of those lost and injured, 18 and 68 were health workers, respectively (WHO, 2015). With these human impacts, there were high demands on the healthcare system that is critical in the immediate aftermath of a disaster for emergency response and long term for the well being of the community.

The paper presents a method for collecting field data after disasters that focuses on assessing the resilience of an individual community sector: healthcare. A structured survey was designed to collect damage and loss-of-function data immediately after the earthquake and recovery data one year after the earthquake. The acute data collection phase focused on damage to structural and nonstructural components and utilities, as well as assess loss of staff and resources supporting key hospital services provided by the facility. The long-term data collection focused on the repair efforts of the physical damage, the recovery of critical lifelines and other resources, and the return of clinical and non-clinical personnel. The paper then presents preliminary data on the impact to a single healthcare facility, Bir Hospital. Bir Hospital is a tertiary referral and teaching hospital located in the heart of Kathmandu City that was established in 1889 and had a capacity of 460 beds before the Gorkha earthquake. Disaster response and recovery differs by community size, organization type, degree of direct seismic impact, and preparedness and mitigation efforts prior to the earthquake; the case study of a healthcare facility presented in this paper is one of several resilience studies by the EERI and PEER teams.

*Keywords: reconnaissance, resilience, Nepal*

## 1. Introduction

The Ministry of Health and Population in Nepal reports that out of the 4,118 public and 350 private health facilities that they oversee, 462 were completely damaged, 765 were partially damaged, and the losses are expected to surpass $63 million US dollars [1]. Additionally, the World Health Organization [2] performed a rapid health assessment of hospitals and healthcare facilities in 12 affected districts in Nepal at the time of the EERI reconnaissance trip (~1 month after the Gorkha earthquake), and found that approximately 90 percent of health care facilities outside main towns were not functioning. The assessment included 21 hospitals in 10 districts (nine private hospitals, eight district hospitals, and four larger central hospitals). Of these, four district hospitals (Chautara Hospital, Ramechhap District Hospital, Rasuwa District Hospital, Trisuli District Hospital) were not functional, with damaged infrastructure (no water supply or power, and perhaps only limited out-patient activities). These four district hospitals were replaced by interim field hospitals that were managed by foreign medical teams. Hospitals in Kathmandu Valley experienced varying degrees of damage, with many red-tagged structures but no catastrophic failures. Many evacuated all patients but were able to maintain a significant portion of their health care services in alternative spaces (e.g., mobile health camps, field hospitals, etc.) in the immediate aftermath of the earthquake. Long-term impacts are still unknown, but assessments by the EERI team, as well as initial reports from the Ministry of Health and Population, indicate that continuity of care in the valley was possible due to the following: creative interventions by healthcare workers; international disaster relief efforts; an enormous (hundreds of thousands of people) outmigration of residents from the valley; the resilience of the healthcare system created by a need to be self reliant before the event; and due to recent activities in disaster preparedness (i.e., staff training at the hospitals).

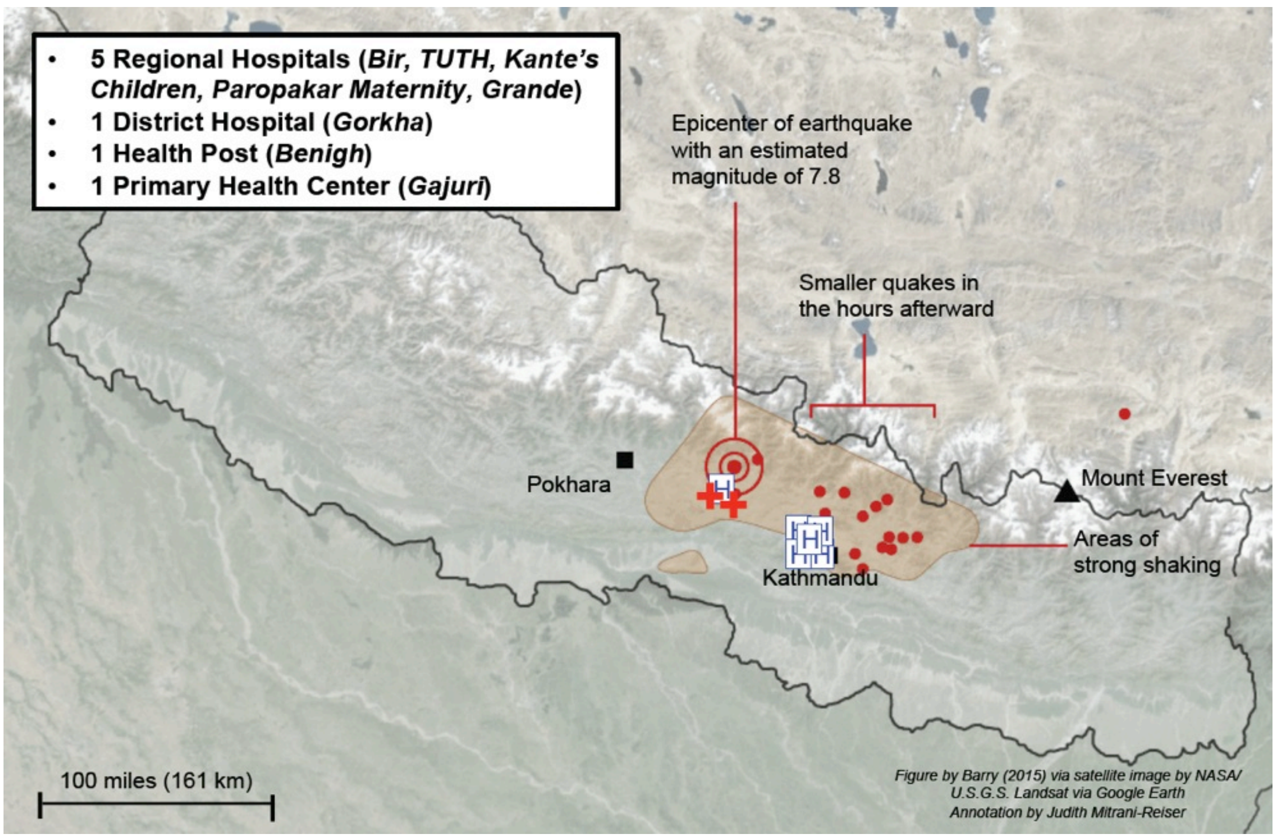



*Fig. 1 – The locations of the five Kathmandu hospitals (squares with the letter 'H') visited by the team in June 2015 and June 2016, and the District Hospital, health post (red cross), and primary health post (red cross) visited by the team in June 2015. The sites of the hospitals are overlaid on a map showing the epicenter of the first event, aftershock locations, and the area where strong shaking was felt.*

## 2. Data Collection Methods

Two international teams visited several health care facilities in June 2015 and again in June 2016. The first visit, part of the EERI/NSET reconnaissance team, was intended to assess the initial impact of the earthquake on the healthcare system in Nepal and the loss of function at these facilities. The second visit (part of the PEER/EERI reconnaissance trip), exactly one year later, was intended to assess any long-term losses still experienced by these facilities in terms of physical and human infrastructure, and also to capture the recovery process in the first year after the event. Together, the data provide: (1) baseline functioning levels for the healthcare facilities, (2) the drop in functioning levels and the facilities' abilities to serve their communities immediately following the earthquake, and (3) longitudinal information to empirically generate resilience curves for the facilities.

During both visits to Nepal, the team surveyed six hospitals in the Kathmandu District, five of them public and one private facility: Bir Hospital, Tribhuvan University Teaching Hospital (TUTH), Kanti Children's Hospital, Paropakar Maternity and Women's Hospital, Nepal Medical College and Teaching Hospital, and Grande Hospital. The teams also visited facilities in the Gorkha District to assess the health care impact closer to the epicenter of the main event. The teams visited the Gorkha District Hospital in 2015 and 2016; smaller facilities, such as the Benighat Health Post and a Gajuri Primary Health Center, were only visited in 2015.

The structured survey tool used in 2015 was originally designed by co-authors Kirsch and Mitrani-Reiser and their colleagues [3] to capture standardized qualitative and quantitative information on the effects of earthquakes to hospital functionality. The original survey was modified slightly to adapt to local building practices. The updated 'Health System Impact Survey' used in June 2015 includes two main sections: one is focused on all physical damage and engineering aspects, and the other is focused on related healthcare and service-area functional impacts. Each of these surveys has multiple sections and can be completed in about an hour with relevant hospital personnel. The engineering survey is typically completed based on interviews with facilities managers and/or engineers. This survey includes the following sections: site and structural description and impact, non-structural description and impact, geotechnical description and impact, supporting documentation (e.g., floor plans or damage photos), and summary of damage and functional disruption to hospital service areas (e.g., emergency department, kitchen, etc.). The healthcare survey is typically completed by interviewing chief medical officers, nursing directors and/or emergency planners, and includes the following sections: baseline hospital information, event impact assessment, response (e.g., number of personnel available in the hours/days following the event) to the earthquake, and final observations (e.g., the major lessons learned after the event). The purpose of this survey is to collect baseline information, capture drops in service levels, and correlate this loss of function to physical damage, and diminished personnel and supplies.

The new 'Health System Recovery Survey' used in June 2016 includes all the components of the original Impact Survey, but was augmented to capture recovery statistics that are necessary for estimating the resilience of the important community healthcare sector. For example, the new survey form tracks the hospital capacity (e.g., number of beds and clinical procedures) of the hospital before the earthquake, one month after the earthquake (first team visit), and one year after the earthquake (second team visit). The augmented engineering survey includes types and times of repairs of the earthquake damage, changes in seismic mitigation practice at the facility (i.e., anchoring equipment and adding backup utility sources), and permanent loss/closure of space. The healthcare survey is intended to track changes in clinical and support staff employed by the facility, supply chains, and throughput of patients at each facility. This survey is also intended to collect qualitative data on external resources (e.g., NGOs) that either aided or hindered response and recovery efforts in Nepal.

## 3. Health System Impact Survey Sample Results

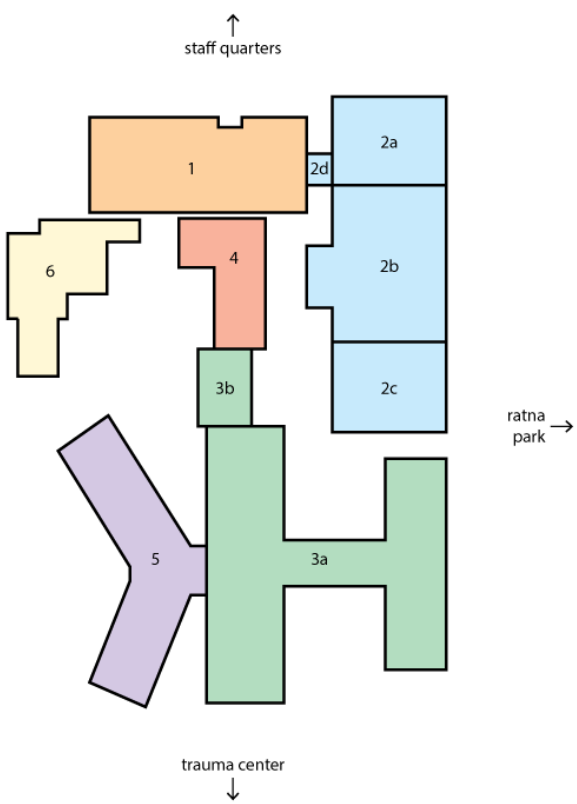
Although many hospitals were visited for this study, results for a single healthcare facility (Bir Hospital) are included in this paper to demonstrate the value of a longitudinal study on healthcare resilience.

### 3.1 Hospital Description

Bir Hospital is a tertiary referral and teaching hospital located in the heart of Kathmandu City. It was established in 1889 and, as of 2013, has a capacity of 460 beds, of which 72% are free of cost [4]. Operated by the National

Academy of Medical Sciences, a government agency, the hospital provides medical services in highly specialized areas, and also offers “undergraduate, postgraduate, and specialization training to medical and nursing students and graduate doctors”[5]. Major departments at Bir Hospital include anesthesia, clinical oncology, surgery, neurosurgery, medicine, nephrology, pathology, radiology, otolaryngology (ENT), orthopedics and traumatology, dermatology and venereology, dental, and emergency [4].

The hospital comprises numerous buildings that support both clinical and nonclinical services and also provide housing for nurses and doctors. Figure 2 shows a schematic of the major buildings at Bir Hospital; the legend provides additional details for each building, including year constructed, number of stories, and structural system. As Figure 2 demonstrates, hospital buildings were constructed over time by different funding agencies, with the oldest building dating back to 1968. Most (if not all) of the buildings at Bir Hospital predate modern seismic design codes and have significant structural vulnerabilities [5].




**LEGEND**

**Building 1: Emergency block**
*Built 1986 by the Government of India*
*5 stories; RC frame w/ masonry infill*

**Building 2: OPD Block**
*Built 1986 by the Government of India*
*5 stories; RC frame w/ masonry infill; three main structures are sepearated by seismic joints*

**Building 3: Surgical Block**
*Built 1968 by the USAID*
*5 stories; RC frame w/ masonry infill; building was initially 3 stories tall*

**Building 4: Old ICU Block**
*Built 1976 by the Government of Nepal*
*5 stories; URM; building was initially 3 stories tall*

**Building 5: New Cabin Block**
*Built late 1970s by the Government of Nepal*
*3 stories; URM; building was initially 1 story tall*

**Building 6: Kitchen and $R_x$ Storage**
*Construction details unknown*

*Fig. 2 – Campus map of Bir Hospital and accompanying legend showing construction details of most buildings on Bir’s campus.*

Bir Hospital receives electricity from the grid via three different connections with different zone coverage, meaning the hospital rarely loses power due to load shedding. In addition, the hospital has two onsite diesel backup generators that supply full power to the emergency block and all operating theaters and post-operative wards. The generators also supply partial power to other wards, the OPD block, and two elevators, but not to the central sterile supply department [6]. It is unclear how long the two generators can supply power to the hospital in the case of grid failure. The hospital obtains its water supply primarily from a single deep bore well located near the staff quarters, but also has water delivered via tanker trucks. Water from the well is treated onsite using a combination of air, sand, and carbon filters and is stored in tanks scattered throughout the hospital, some underground, some on rooftops. The total capacity of onsite water storage is 425,000 liters, which provides enough supply for approximately one day of normal usage [5]. Bir Hospital has a central system that supplies oxygen to select parts of the hospital, including operating theaters and post-operative wards. This central system is fed by a manifold of thirty oxygen cylinders, which are delivered by truck to the hospital on a daily basis [5]. The hospital has enough cylinders stored onsite for approximately one day of normal usage and relies on a single oxygen provider. In parts of the hospital not supported by the central system, oxygen is supplied through individual cylinders. For communication, the hospital relies on a combination of landline and cellular phones.

## 3.2 Physical Damage

Bir Hospital's heterogeneous building stock suffered significant damage, resulting in four yellow tags and one red tag on its campus. Building 1, the Emergency Block (see Fig. 3a), did not suffer structural damage but did suffer significant damage to its masonry infill walls at the ground floor and to tiles in corridors and near elevators (see Fig. 3c), creating falling hazards for occupants and resulting in a yellow tag. Building 2, which comprises several large buildings (2a - 2c) and one smaller one (2d), did not suffer structural damage; the larger buildings were considered safe (green tag) for occupancy after the earthquake, while the smaller building 2d was assigned a (local) yellow tag for severe damage (out of plane rotation) to a masonry infill wall caused by pounding with Building 1. The seismic gap between Buildings 1 and 2d is only 80mm, which is not sufficient to prevent pounding during strong ground shaking. Building 3, the surgical block, did not suffer structural damage, but like the other buildings on campus, it suffered significant damage to its nonstructural masonry walls at the ground floor, resulting in a yellow tag. Buildings 4 and 5 are unreinforced masonry (URM) buildings that were vertically augmented from 3 to 5 stories and from 1 to 3 stories, respectively. Building 4 was green tagged after the earthquake and suffered damage to a stairwell connecting it to Building 3. Building 5, which had diaphragm discontinuity between ground and first floors, suffered significant structural damage in the bottom two floors and widespread nonstructural damage; this building has since been demolished. Building 6, which housed the kitchen, maintenance section, general store, and medical store, suffered floor settlement and significant nonstructural damage; this building has since been partially demolished.

There was a wide range of performance of municipal services, such as power, water, and communication lifelines at the hospitals visited by both teams. Bir Hospital lost municipal power for one day, but had no trouble supporting hospital functions with its onsite backups including: (1) one manually operated diesel generator (165 kVA); (2) two (recently acquired) 250 kVA generators; and (3) battery backup supplied by solar panels installed less than one year before the earthquake. Ninety percent of the water supplied to Bir comes from its own well. The earthquake disrupted water supply from their borehole for one week; tankers brought in from the Nepalese Army supplemented the hospital's water supply. The hospital suffered no major impact to its communication system, other than overloaded cellphone networks in the hours following the earthquake, which made it difficult for staff to communicate internally and externally.

The hospital did not suffer significant damage to medical equipment or disruption of medical gases and supplies. One computed radiography (CR) machine (shown in Fig. 3d) fell off a table during the earthquake, damaging the equipment. The hospital's oxygen is supplied using cylinders that are delivered every day; these cylinders were not restrained at the time of the earthquake and many fell, creating loud crashing noises that frightened occupants. There was no disruption in oxygen delivery after the earthquake. The hospital's medical care supplies were supplemented by NGOs and the WHO for three weeks after the earthquake.

## 3.3 Loss of Hospital Functions

The most significant challenge to maintaining functionality at Bir Hospital involved coping with structural and nonstructural damage to buildings. As detailed in the previous section, utilities like electricity, water, and communications were available immediately after the earthquake; however, damage to facilities forced the evacuation of all patients and shuffling of services to temporary spaces.

*Evacuation*

Immediately following the earthquake, many patients self evacuated and left completely while other patients were assisted in their evacuation by hospital staff. For several hours, physicians and nurses treated patients in the streets and in tents at the park across the street. After approximately three hours, staff began moving patients and important medical equipment to the trauma building at the south end of the hospital (see Figure 2), which was unoccupied at the time of the earthquake. Within a day all patients and equipment had been transferred. For the next week or two, the hospital struggled with patient management, especially directing incoming patients to the temporary service areas set up in the trauma center. Within a month, the hospital had shifted most services back to their original locations, with the exception of those provided in the New Cabin Block, which was red tagged after the earthquake.

*Number of beds*

Because a significant portion of the hospital's buildings were either yellow or red tagged, the number of available beds decreased after the earthquake. Before the earthquake, the hospital had a total of 460 non-monitored beds. One month after the earthquake, the hospital had 396. One year later it had 404, with much of the decrease due to demolition of the New Cabin Block (Bldg 5) with its 78 beds. In addition, the number of ICU beds dropped from 31 before the earthquake to 21 one month after, where it remained for the next year. Again, the demolition of the New Cabin Block, which had 15 ICU beds before the earthquake, likely contributed to this drop in capacity. In contrast, the number of outpatient beds did not change in the month after the earthquake, though the outpatient department was closed for a week to accommodate the surge of trauma patients.

*Hospital Supplies and Treatment Areas*

Bir Hospital never ran out of medical care supplies, such as medicine, dressing and splints, surgical supplies, IV equipment and fluids, and personal protective equipment. However, there was a 3-week disruption in normal suppliers and required emergency resources (e.g., World Health Organization and other NGOs).

The hospital partially suspended delivery of the following hospital services: inpatient medical and surgical care, adult monitored cardiac care, medical and surgical ICU care, and in-patient surgeries. The emergency department services were able to continue functioning, as well as most support services (e.g., laboratory testing, radiology, pharmacy, administrative, medical records, and housekeeping). The hospital lost all kitchen service for two days, and had food supplemented by NGOs.

While the hospital lost several operating theatres (OTs) after the earthquake, it was able to use alternative space in a newly built Trauma Center across the street in order to maintain surgical functionals. For the first month (and possibly longer), the hospital was without two of its seven inpatient OTs and one of its two outpatient OTs. During this time, hospital staff were able to perform 842 major and minor operations in May 2015, an increase of 42% from May 2014. One year after the earthquake, the hospital was still without one of its inpatient OTs, though both outpatient OTs were functional.

## 3.3 Hospital Resilience

Despite losing a significant amount of space after the earthquake, the hospital was remarkably resilient, as detailed in the following sections.

*Staffing*

Because the earthquake struck on a Saturday afternoon, staffing at the hospital was lighter than normal for the first 24 hours after the earthquake. For the first six hours after the earthquake, there was a shortage of both qualified (e.g., physicians, nurses, and other clinical staff) and non-qualified personnel to manage the surge of patients. Overloaded cell phone networks made it difficult to reach staff initially, both outside of the hospital and within, which likely contributed to the delay in some personnel reporting to work. Once onsite, staff communicated with each other via radios held by security personnel. Helping to mitigate the initial shortage of staff was a significant population of residents who lived onsite and were given a one-month break from their studies to care for patients, both at Bir Hospital and further afield. In addition, the hospital received temporary qualified staff (e.g., physicians, nurses, and paramedics) from India, Spain, Russia, and the United States for the first week. The hospital also received temporary non-qualified volunteers from local and foreign organizations who helped with patient transfers and distribution of water and medicine for the first two weeks. Consequently, staffing levels were back to normal two weeks after the earthquake. One year later, the number of staff employed at the hospital remained unchanged relative to before the earthquake, with no change in the rate of staff turnover.


(a) (b) (c) (d)

*Fig. 3 – (a) Street entrance to Building 1, the Emergency Block, (b) example of cracking in masonry infill walls, (c) example of tile cracking and (d) damaged CT machine (photos: Hari Kumar and Judith Mitrani-Reiser).*

*Patient surge*

When the earthquake struck, there were 337 patients at the hospital. Staff attempted to discharge some of these patients in the first 24 hours to make room for the expected surge, but many had no where to go and therefore stayed at the hospital (though small number of patients self-discharged). The hospital also closed its outpatient department for one week. In the month following the earthquake (i.e., May 2015), Bir Hospital treated 2,462 trauma cases, resulting in 427 admissions and 842 operations, both major and minor. In comparison, one year before the earthquake (i.e., May 2014) the hospital performed 590 operations, while one year after (i.e., May 2016) the hospital performed 549. In general, the demand for inpatient services remained higher than normal for two weeks, but returned to normal within a month. Bir Hospital also accepted patients transferred from other hospitals and facilities, including two with spinal injuries. While there were no injuries or deaths from earthquake-induced damage onsite, the hospital reported 117 earthquake-related deaths in the first month.

*Clinical services*

The earthquake impacted the ability of staff to provide clinical services. For one week, the hospital stopped providing all outpatient services, resulting in a decrease in the number of visits after the earthquake. In May of 2014, one year before the earthquake, the outpatient clinic saw 29,069 visits. In contrast, in May of 2015, the month after the earthquake, outpatient visits dropped to 13,661. One year after the earthquake, outpatient visits had rebounded to 28,308 in May 2016. In spite of damage to and evacuation of several hospital buildings, there was no reduction in the number of surgical procedures immediately after the earthquake. There was also no reduction in the quality of surgical procedures due to an influx of medical equipment donations from the Nepal government and NGOs. One year after the earthquake, however, the hospital was coping with the demolition of the New Cabin Block and its 78 beds. While some services have been relocated to other buildings, including female medicine and oncology, others have been reduced (e.g., ICU) or disrupted entirely (e.g., burn unit, plastic surgery, isolation).

*Preparedness*

When the earthquake struck the hospital was in the process of developing an emergency response plan, which has since been completed. In addition, the hospital has also established a disaster management committee.

## 4. Conclusion

Prior to the earthquake, Bir Hospital faced operational challenges on a daily basis (e.g., lack of reliable municipal power and water supplies) that in many ways made it more self-sufficient and therefore better prepared for earthquakes. This was a theme throughout most of Nepal, whose people exhibited a remarkable degree of resilience after the earthquake.

However, many hospital buildings had (and still have) serious structural vulnerabilities, which manifested themselves to a limited degree after the earthquake. Throughout the weeks and months after the earthquake, lack of space was a serious issue. Luckily the hospital had an unoccupied building when the earthquake struck. Still have damage to buildings and equipment that needs to be repaired.

## 5. Acknowledgements

This work could not be possible wihtout the support of Sunil Khadka (Infrastructure Planning Adviser at the Ministry of Health and Population) and Hima Shrestha (Director of Earthquake Engineering and Training at NSET), who toured facilities with us and were an integral part of our team and studies. We would also like to graciously acknowledge the directors, facilities managers, and staff at the hospitals and at the Ministry of Health and Population, who shared their time and experiences with us.

## 6. Copyrights



## 7. References

[1] (NMHP) Nepal Ministry of Health and Population, 2015. "Post Disaster Needs Assessment and Recovery Plan of Health and Population Sector," June 10, 2015.

[2] (WHO) World Health Organization, 2015. "WHO briefs partners on Nepal earthquake," (http://searo.who.int/entity/emergencies/crises/nepal/who-briefs-partners-on-nepal-earthquake/en/), accessed on 15 Aug 2016.

[3] Mitrani-Reiser, J., Mitrani-Reiser, J., Mahoney, M., Holmes, W.T., de le Llera, J.C., Bissell, R., and Kirsch, T.D., 2012. "A Functional Loss Assessment of a Hospital System in the Biobío Province." Earthquake Spectra, 28(S1): pp. S473-S502.

[4] (NAMS) National Academy of Medical Sciences, 2014. http://nams.org.np/about.php (accessed on 17 August 2016)

[5] (GHI) GeoHazards International, 2013. "Initial Seismic Vulnerability Assessment of Equipment, Utilities, Architectural Shell and Contents at National Academy of Medical Sciences (Bir Hospital) Kathmandu, Nepal," Report prepared for WHO Regional Office for South-East Asia, July 31, 2013.

[6] (NSET) National Society for Earthquake Technology, 2002. "A structural vulnerability assessment of hospitals in Kathmandu Valley." World Health Organization and Ministry of Health and Population. Retrieved from http://www.nset.org.np/nset2012/images/publicationfile/20130101161352.pdf ~~2002)~~