

SPECIAL ARTICLE

Implications of Hospital Evacuation after the Northridge, California, Earthquake

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ABSTRACT

BACKGROUND

On January 17, 1994, an earthquake with a moment magnitude (total energy release) of 6.7 occurred in Northridge, California, leading to the evacuation of patients from several hospitals. We examined the reasons for and methods of evacuation and the emergency-management strategies used. The experience in California may have implications for hospital strategies for responding to any major disaster, including an act of terrorism.

METHODS

From September 1995 to September 1996, we surveyed all acute care hospitals in Los Angeles County that reported having evacuated patients after the Northridge earthquake. Physicians, nurses, hospital administrators, and staff on duty at the hospitals during the evacuation responded to a 58-item structured questionnaire.

RESULTS

Eight of 91 acute care hospitals (9 percent) were evacuated. Six hospitals evacuated patients within 24 hours (the immediate-evacuation group), four completely and two partially. All six cited nonstructural damage such as water damage and loss of electrical power as a major reason for evacuation. Five hospitals evacuated the most seriously ill patients first, and one hospital evacuated the healthiest patients first. All hospitals used available equipment to transport patients (blankets, backboards, and gurneys) rather than specialized devices. No deaths resulted from evacuation. One hospital evacuated patients after 3 days and another after 14 days because of structural damage, even though initial inspections had shown no damage (the delayed-evacuation group). Both hospitals required demolition. Some hospitals identified destinations for their evacuated patients independently, whereas others sought the assistance of the Los Angeles County Emergency Operations Center; the two strategies were equally effective.

CONCLUSIONS

After even a moderate earthquake, hospitals are at risk for both immediate nonstructural damage that may force them to evacuate patients and the delayed discovery of structural damage resulting in permanent closure. Evacuation of large numbers of inpatients from multiple hospitals can be accomplished quickly and safely with the use of available resources and personnel.

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EARTHQUAKES POSE A SERIOUS THREAT to the lives of people throughout the world. In the United States, the problem affects not just Californians but also sizable populations along the entire West Coast, the Midwest, and even sections of the eastern seaboard. Local hospitals are the initial sources of medical care after any major disaster. However, hospitals have been as vulnerable to the destructive power of earthquakes as the populations they serve. The 1971 earthquake in California's San Fernando Valley caused severe structural damage to four hospitals, forcing the evacuation of patients and permanent closure.¹

Uncertainty about the seismic durability of hospitals raises important issues for physicians, members of emergency medical services, and disaster planners, including questions about the best strategies for evacuating hospitals when necessary. There are reports of hospital evacuation in the medical literature, but most have involved the evacuation of a single hospital after an event such as a flood.¹⁻⁷ We conducted a systematic analysis of the evacuation of inpatients from multiple hospitals as a result of an earthquake in Northridge, California, and the implications for the community.

The earthquake in Northridge, Los Angeles County, had a moment magnitude (or total energy release) of 6.7 (moderate magnitude). It began at 4:31 a.m. on January 17, 1994. The purpose of our study was to assess the hospital evacuations after this earthquake and the emergency-management strategies that were used. The problem of hospital evacuation is particularly relevant in view of the increased concern about terrorism, including the possible use of explosive devices or other weapons of mass destruction. Since hospitals might be forced to evacuate patients quickly after contamination from a terrorist attack, such analyses may be useful to medical providers and administrators who prepare for and manage emergency evacuations.

METHODS

SELECTION OF HOSPITALS

Our study was an observational, retrospective investigation of all acute care hospitals in Los Angeles County, California, that reported the evacuation of at least one inpatient because of damage from the Northridge earthquake. Eligible hospitals were identified through a review of records from the Los Angeles County Department of Health Services and

the California Office of Statewide Health Planning and Development.

QUESTIONNAIRE

We developed a structured questionnaire for administration to hospital personnel who had been on duty during the earthquake and the subsequent evacuation of patients. The questionnaire consisted of 58 questions derived from a review of the literature on the evacuation of hospitals, related articles in the fields of earthquake engineering and emergency medical services, and our personal knowledge and experience.^{1-6,8} The topics covered basic characteristics of the hospital triage strategies, structural damage (defined as the compromise of essential load-bearing components of the building), nonstructural damage (defined as the failure of other components of the building, such as plumbing, electrical systems, heating, and air conditioning), and reasons for and methods of evacuation.

SURVEY DESIGN

After agreeing to participate in the study, the director of each hospital designated an interview team. This team included, at a minimum, a physician, a nurse, an administrator, and one other hospital employee from a group not already represented (usually a member of the maintenance staff), all of whom had been present during the evacuation. Each hospital received a copy of the questionnaire in advance so that the survey participants could review it before the scheduled two-hour interview. Each question was posed to the group as a whole, and the answers were recorded. Because of logistical problems, four individual interviews were also conducted, two by telephone and two in person. One of us conducted all the interviews between September 1995 and September 1996. The institutional review board at the Harbor–University of California, Los Angeles, Research and Education Institute approved the study.

RESULTS

HOSPITALS

At the time of the earthquake, there were 91 acute care hospitals in Los Angeles County. Eight of these hospitals (9 percent) reported that they had evacuated at least one inpatient as a result of damage from the earthquake. All eight hospitals participated in the study (Table 1).

Six institutions began evacuating patients within hours after the earthquake and completed the process by the end of the first day (the immediate-evacuation group). One hospital did not evacuate patients until 3 days after the event, and another did not do so until 14 days afterward (the delayed-evacuation group). Six of the eight hospitals were completely evacuated, and four of these six were scheduled for demolition. Although no formal evaluation of the decision-making process was reported, it was believed at all eight institutions that evacuation was necessary.

EVACUATION OF PATIENTS

Of the six hospitals that evacuated patients immediately, four evacuated all inpatients, and two evacuated some inpatients (Table 2). Five of the six hospitals cited nonstructural damage as the main reason for evacuation; the sixth hospital cited both structural and nonstructural damage. All hospitals identified the types of nonstructural damage that prompted the decision to evacuate patients. Five facilities cited extensive water damage from burst pipes, fire sprinklers, and ruptured rooftop water tanks as a major factor. Other reasons included loss of electrical power (cited by three hospitals) and an inability to provide medical care (cited by five hospitals, including the three that cited power failure) as a result of inoperative ventilation and fire-suppression systems and the destruction of medical supplies or equipment.

The two hospitals that did not evacuate patients immediately also sustained nonstructural damage, but it was not as extensive as that of the other six hospitals. Therefore, they were not initially forced to evacuate patients. The decision to evacuate patients at these two institutions was based on the delayed identification of serious structural damage. Each of the two hospitals passed inspections made initially by in-house personnel and later by local structural engineers. One hospital was condemned 3 days after the earthquake and the other 14 days afterward; both had already resumed normal operations. A total of four hospitals were ultimately demolished.

TRIAGE AND MOVEMENT OF PATIENTS

At five of the six hospitals that evacuated patients immediately, there appeared to be no imminent threat to the safety of patients, so rapid evacuation was considered unnecessary. These facilities elected to evacuate the most seriously ill patients first.

Table 1. Characteristics of the Eight Study Hospitals.

Hospital No.	Type	No. of Inpatients at the Time of the Earthquake	Intensive Care Unit	No. of Stories
1	Trauma center	310	Yes	5
2	General hospital (private)	87	Yes	3
3	Veterans Affairs hospital	334	Yes	6
4	Trauma center	176	Yes	3
5	General hospital (county)	280	Yes	6
6	General hospital (private)	295	Yes	6
7	Pediatric hospital	74	Yes	8
8	Psychiatric hospital	114	No	8

Initially, supervisors moved patients to safer areas of the hospital or outdoors, using available equipment such as backboards, wheelchairs, blankets or sheets, and gurneys. Since elevators were not operating, stairs were used for evacuation between floors. Medical staff then discharged some patients home and transferred the rest to other hospitals in the area. Medications and medical records accompanied almost all patients who were transferred elsewhere. Staff members traveled with critically ill patients and vehicles containing multiple patients during transfer. Hospital staff did not accompany individual patients in stable condition.

Four of the six institutions in the immediate-evacuation group evacuated patients from intensive-care units. Some of these patients were receiving mechanical ventilation. Since all these units lost electrical power, hospital personnel provided ventilatory support manually. After a brief period, emergency generators restored the electrical power required for mechanical ventilation, except in one hospital. Manual ventilation was also provided while the patients were being evacuated and transferred by ambulance to other hospitals.

Personnel at one institution (Hospital 3) believed that the patients were in immediate danger and therefore wanted to evacuate them as rapidly and efficiently as possible. This institution moved the healthiest patients first and successfully evacuated all 334 patients to open areas adjacent to the buildings in two hours, including patients in a six-story structure containing the intensive care unit. Using flashlights, staff members first escorted all ambu-

Table 2. Evacuation Data.

Hospital No.	Timing of Evacuation	Evacuation Status	Reason for Evacuation	No. of Patients Transferred to Other Hospitals	Management of Transfers [*]	Time to Evacuation [†] <i>hr</i>
1	Immediate	Partial	Nonstructural damage	25	Hospital	13
2	Immediate	Partial	Nonstructural damage	2	Hospital	1
3	Immediate	Complete	Structural and nonstructural damage	320	Hospital	9
4	Immediate	Complete	Nonstructural damage	125	County	19
5	Immediate	Complete	Nonstructural damage	270	County	9
6	Delayed	Complete	Structural damage	202	Hospital	10
7	Delayed	Complete	Structural damage	46	County	12
8	Immediate	Complete	Nonstructural damage	76	Hospital	13

* County refers to the Los Angeles County Emergency Operations Center.

† The time to evacuation denotes the time from the beginning of the evacuation process to the departure of the last patient from the hospital grounds.

latory patients out of the building through the stairwells, starting on the bottom floor and working their way up. Because of the extensive damage, the emergency generators failed and electrical power was completely absent. Next, patients who could not walk but who were otherwise self-sufficient were evacuated with the use of wheelchairs and mattresses. Finally, patients in the intensive care unit were taken out of the building. Staff members provided manual ventilation for all intubated patients for a total of two hours — the time required to transport all patients in the intensive care unit to safe open areas. At this point, personnel obtained small portable generators that supplied enough power to operate the ventilators on the lawn. Trapped patients did not receive attention until all other patients had been evacuated. The last patient to leave the building was a person trapped behind a partially collapsed door. Specialized equipment, such as infant carriers, stair chairs, and earthquake slides, was not used at this hospital or at the other five hospitals.

The triage and movement of patients were not

serious issues at the two hospitals that evacuated patients after a delay. By the time the patients were evacuated, power had been restored, permitting the use of elevators that had been inspected by hospital staff members and declared safe. Both hospitals used gurneys and wheelchairs to move the patients, evacuating them as ambulances became available.

MANAGEMENT OF TRANSFERS

Four of the six hospitals that evacuated patients immediately contacted nearby facilities to arrange for the patients to be transferred. Although telephone service failed periodically, it functioned consistently enough for the hospitals to make these arrangements. Of the other two hospitals, one relied partially and one completely on the Los Angeles County Emergency Operations Center to arrange transfers. All six hospitals asked the center to dispatch vehicles for use in transporting patients.

Hospital staff members transferred patients who were in stable condition with the use of private cars, public buses, and hospital vans. Ambulances and

helicopters were reserved for more seriously ill patients, such as those receiving ventilatory support. In the immediate hours after the earthquake, one institution used a television-news helicopter to transport a patient with potential intracranial bleeding. Since most transfers were not made on an emergency basis, the hospitals spread the use of ambulances throughout the day. Space was eventually found to accommodate all patients, even though some were taken to hospitals that were more than 80 km (50 mi) away.

Two institutions in this group evacuated some of their pediatric patients to a children's hospital 32 km (20 mi) away, in an area thought to be outside the earthquake zone. The receiving hospital was Hospital 7 in our study. Some of the children initially transferred to this hospital were reevacuated when it was condemned 14 days later.

One of the hospitals that evacuated patients after a delay relied on the Los Angeles County Emergency Operations Center to arrange the transfers; the other hospital found destinations for patients independently. The small number of hospitals precluded statistical analysis of the time required for evacuation. However, there was no marked difference in the time required to complete the evacuation process between hospitals that relied on the Emergency Operations Center and those that arranged transfers independently (Table 2). All facilities depended heavily on telephone communication (land lines, cellular phones, and faxes) to coordinate these transfers.

All the hospitals maintained logs that matched patients' names with the institutions to which they were transferred. Family members who contacted the evacuated hospitals were referred to the facilities where the patients were taken.

No deaths occurred as a result of the evacuation process. One patient unintentionally extubated himself during evacuation but was reintubated without incident. The interviewees reported no other adverse events associated with the evacuation process among patients or staff members.

DISCUSSION

Hospital services have a crucial role in the initial medical response to large earthquakes, but the seismic stability of hospital facilities remains uncertain. The California Office of Statewide Health Planning and Development has reported that 48 percent of the state's hospital buildings are at high risk for col-

lapse or loss of function from structural failure after an event similar in magnitude to the Northridge earthquake.⁹ In addition, at 91 percent of California hospitals, nonstructural components that are essential to the safety and care of patients will fail or be seriously damaged after a strong earthquake. These factors, combined with the risk to hospitals posed by other sudden disasters, including terrorist attacks with the use of explosive or biologic weapons, underscore the need to identify the important issues involved in evacuating hospitals.

Our findings suggest that after a moderate earthquake, hospitals may need to evacuate patients immediately because of nonstructural damage, and delayed identification of structural damage may result in permanent closure. Triage strategies for moving either the most or least seriously ill patients first may be effective, and special devices for moving patients may be unnecessary. Hospitals can safely and effectively evacuate large numbers of patients with or without assistance from the county emergency operations center. A backup plan for providing care outside a hospital setting is imperative, in case the receiving hospitals become nonfunctional or are overwhelmed.

Our study showed that nonstructural damage caused the greatest initial concern about patients' safety. Within hours after the Northridge earthquake, six hospitals decided to evacuate patients because extensive nonstructural damage made patient care nearly impossible. The most serious nonstructural damage involved the leakage of water from ruptured sprinklers, rooftop tanks, and other plumbing fixtures. Ukai reported similar findings in hospitals damaged by the Hanshin-Awaji earthquake in 1995.¹⁰

For the two hospitals that did not immediately evacuate patients, the evacuation decision was based solely on the presence of structural damage. Inspectors discovered serious flaws and condemned the buildings. These two hospitals were not forced to implement a triage strategy because they had electric power, water, functional equipment, and the use of their elevators during the evacuation process. Using standard devices (gurneys and wheelchairs), these two institutions evacuated each patient as an ambulance became available.

In contrast, the six hospitals that evacuated patients immediately could not use their elevators and had limited electric power. They therefore had to make decisions about the order in which patients would be moved and the method of transportation.

In five of the six facilities, personnel moved the most severely ill patients first. This strategy offers the advantage of lessening the burden on hospital staff, since the patients who are the most seriously ill require the most resources. In addition, since resources are rapidly depleted after an earthquake, it makes sense to start by transferring the patients whose care requires the greatest resources. The inefficiency of this technique was not relevant, since there was no immediate threat to patients' safety. Personnel at the sixth institution, fearing the collapse of hospital buildings, decided an efficient evacuation was mandatory. This hospital chose to evacuate the healthiest patients first, a strategy that permitted the evacuation of large numbers of patients in a short time. The ability of this institution to move 334 patients from buildings to open areas in two hours suggests that evacuation of the healthiest patients first may be an effective strategy when speed is essential. No deaths were associated with either strategy.

Staff members at the six hospitals that evacuated patients immediately moved all patients through the stairwells using improvised transport devices such as blankets, backboards, and mattresses. All six hospitals were satisfied that this equipment was adequate, suggesting that it may not be necessary to purchase such specialized devices as stair chairs, infant carriers, and earthquake slides.

The Los Angeles County Emergency Operations Center and area hospitals were concerned about possible structural damage and building safety immediately after the earthquake. In all cases, building inspectors were asked to confirm the integrity of hospital structures.

Hospital employees performed the initial inspections, followed by private firms or government agencies. Six of the eight hospitals passed the initial inspection and at least one subsequent inspection. However, two of these six facilities were condemned 3 and 14 days later, when further examination revealed serious structural flaws. We could not identify the factors that led to the change in building status. These findings suggest that a degree of uncertainty is inherent in the inspection process and that hospitals initially thought to be safe may subsequently be condemned.

Many regional disaster plans call for centralized direction of the evacuation process by an emergency operations center. Hospitals provide the center with information about the number of patients to be evacuated and the severity of each patient's con-

dition. The center then contacts other facilities in the area and arranges for the patients to be transferred. Two of the six hospitals in our study that evacuated patients immediately relied on such assistance in whole or in part. The other four institutions, including the one where structural damage was thought to pose an imminent threat to the safety of patients, arranged for transfers without the assistance of the Los Angeles County Emergency Operations Center. They used telephone systems to contact neighboring hospitals and arrange for the transfers. These hospitals did contact the center to obtain assistance in finding transport but also used whatever vehicles were in the area.

If many patients need to be moved out of the hospital, it may be desirable to have the emergency operations center manage the transfers, conditions permitting, but hospitals also appear to be able to manage transfers independently, if necessary. Regional disaster plans should include provisions for independent management of transfers in case management by the center is not possible or desirable. It remains unclear how successful the evacuation operation after the Northridge earthquake would have been if telephone communication had been completely disrupted for the first 24 hours.

Finally, emergency planners should consider establishing a backup plan to provide immediate advanced medical care in the event that hospitals are overwhelmed or become nonfunctional. Historically, little attention has been paid to the hospital-as-victim scenario. In fact, national disaster systems are only beginning to focus on the lack of resources to deal with a sudden large increase in the volume of patients (surge capacity). Planners need to find creative solutions to this problem, such as the establishment of field hospitals and use of alternative sites of care (e.g., schools, sports facilities, or churches). As of January 2001, the emergency-management standards established by the Joint Commission on Accreditation of Healthcare Organizations require that all accredited hospitals identify alternative sites of care. Hospitals must ensure that necessary medication, equipment, personnel, and medical records are provided at these sites.

Creating a hospital backup system to provide acute medical care may also be prudent. Japanese researchers came to a similar conclusion after the 1995 earthquake in Kobe, Japan.^{11,12} The Medical Disaster Response model is one such system, although it was not in place after the Northridge earthquake.¹³

The problem of surge capacity is not limited to earthquakes. Terrorist attacks targeting large populations with biologic weapons might result in thousands of victims. No hospital can absorb such a large volume of patients and maintain currently accepted standards. One solution is to use hospital facilities other than inpatient units, such as on-site clinics or offices, for the temporary provision of inpatient care. Another option is to take patients to designated facilities in the community. A federal plan still under development incorporates this strategy.¹⁴ In addition, the use of community centers to provide initial care preserves hospital resources for the most seriously ill patients.

Our findings have important implications for clinicians, hospital administrators, emergency managers, and researchers preparing for hospital evacuations after earthquakes and other sudden-impact disasters, including terrorist acts.

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