ORIGINAL CONTRIBUTION
earthquake;
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The 1988 Earthquake in Soviet Armenia: A Case Study

A major earthquake devastated the Armenian Republic of the Soviet Union on December 7, 1988, resulting in thousands of deaths and injuries. In a postearthquake investigation of three towns seriously affected by the earthquake, we studied earthquake-related injury patterns, made observations on rescue and medical efforts, and postulated certain factors associated with increased morbidity and mortality. Information was obtained from official Soviet documents, interviews with survivors of the earthquake, and interviews with local, regional, and national government officials. Figures were based on assessments made by these officials in the field in the immediate postearthquake period. Out of a population of 8,500, there were 4,202 (49.4%) deaths and 1,244 (14.6%) injured (casualty rate, 64.0%). Deaths and injuries were 67 and 11 times higher, respectively, among trapped than nontrapped victims. Being outside at the time of the earthquake or having escaped to the outside from the collapsing structure was crucial for survival. Among persons found alive, 89% were rescued during the first 24 hours, mostly without the use of heavy equipment. This observation underscores the importance of swift rescuer response. As with all field surveys after disasters, there were methodological limitations to this study due to chaotic postearthquake conditions. Accordingly, results must be approached with caution. Nonetheless, these preliminary observations are striking and have generated several new hypotheses for further investigations using more sophisticated analytic methods. [Noji EK, Kelen GD, Armenian HK, Oganessian A, Jones NP, Sivertson KT: The 1988 earthquake in Soviet Armenia: A case study. Ann Emerg Med August 1990;19:891-897.]

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INTRODUCTION

During the past 20 years, earthquakes have caused more than a million deaths worldwide. Better epidemiological knowledge of the causes of death and the type of injuries and illnesses caused by earthquakes is clearly essential for determining appropriate relief supplies, equipment, and personnel.[1-4] On December 7, 1988, an earthquake registering 6.9 on the Richter scale hit the northern part of the Armenian Soviet Socialist Republic, one of the most seismically active regions of the Soviet Union[5-8] (Figure 1). Caused by movement along a geological fault near the town of Spitak in the northwestern part of the country, the quake affected 40% of the national territory.[9,10] Of the 150 villages damaged, 58 were destroyed. A high percentage of Armenia's housing (11%) was destroyed or rendered uninhabitable, and 500,000 to 700,000 persons were made homeless.[11] Bridges, lifelines (eg, water, power, gas, sewage systems), and industrial facilities were also severely damaged.[12] The toll in human terms was devastating: approximately 40,000 persons were reported trapped in collapsed buildings — 15,000 were successfully rescued, and 25,000 bodies were recovered from the rubble. Another 31,000 were known to be injured, of whom 12,200 required hospitalization.[11,13]

We undertook this survey during the period immediately after the earthquake to assess the epidemiologic impact of the disaster and to develop an understanding of the relationships among building characteristics, occupant actions, search and rescue, medical care, and patient outcome.

TABLE 1. *Location of individuals and entrapment status: Association with death and injury*

Location of Individuals	Population	Deaths (%)	Relative Risk (95% CI)	Survivors	Injured (%)	Relative Risk (95% CI)
Outside	651	8 8	1 0	594	1.7	1.0
Inside	7,120	55 1	6 3 (5.4–7 4)	3,197	36 3	21.6 (15.1–30 9)
Unknown	729	30 5		507	14.6	
Total	8,500	49 4		4,298	28.9	
Nontrapped Persons	3,390	1.2	1 0	3,349	8.8	1.0
Trapped Persons	5,110	81 4	67 3 (49.7–91.3)	949	100.0	11.4 (10.2–12.7)

CI, confidence interval.

FIGURE 2. *Main street in Nalband showing complete collapse of all buildings. Note complete collapse of precast-concrete frame school building on right side of street.*

a strict registration of all deaths, including circumstances of death, had been conducted, all statistics presented here should be considered approximations and, in some cases, anecdotal. For example, population figures for the three towns were taken from a census conducted in 1979. It is unknown what percentage of households were interviewed or how systematically the survey was carried out. Unfortunately, we were not able to determine the number of persons successfully extricated who died later.

The data were analyzed with the aid of the Statistical Analysis System (SAS Institute, Cary, North Carolina). The analyses included relative risk calculations and χ^2 tests of proportion for simple comparisons. Statistical significance was considered at $P < .05$.

RESULTS

In the three towns, the crude death rate (the percentage of residents found dead on extrication) was 49.4%, with a crude injury rate of 28.9% and an overall casualty rate (deaths and injuries) of 64.1% (Table 1). At the time of the impact, most (83.8%) of the people were indoors. The mortality rate was significantly greater for these individuals (55.1%) than for those who were outdoors (8.8%) ($P < .01$) (Table 1). Injury rates were also significantly greater for those inside (36.3%) than for those outside (1.7%) ($P < .01$) (Table 1).

Of the total population, 60 1% were reported to have been trapped. Death rates were 81.4% for trapped individuals as compared with a rate of 1.2% for those who were not trapped ($P < .01$). Injury rates were 100% and 8 8%, respectively, for the same groups (Table 1). Thus, deaths were 67 times and injury rates 11 times higher among trapped than nontrapped victims. The casualty rates were reported to be 100% for trapped people as compared with a rate of 9.9% for nontrapped individuals. For those trapped, the ratio of injuries to deaths was 0.23, whereas for nontrapped individuals, it was 7.2.

All buildings in the three towns sustained severe damage or complete collapse. Almost all of the residential dwellings were one-story unreinforced stone masonry structures built from carved blocks of tuff (a lightweight, volcanic stone) set in mortar to form walls. Most of these dwellings partially or totally collapsed. There were two types of precast concrete buildings in the three towns. Precast concrete elements refer to concrete structural components that have been fabricated at a factory and then transported to the construction site for erection compared with poured-in-place concrete elements. Most industrial facilities in the towns studied were of the precast-concrete frame type, consisting of precast concrete columns and beams welded or tied together to form frames (Figure 2), there was a smaller inventory of precast-concrete panel structures. Of these three types of building systems, poorly reinforced or unreinforced stone masonry build-

TABLE 2. *Effect of building type on survival in Nalband*

Building Type	Buildings	Occupants	Death Rate (%) (N)	Relative Risk	95% Confidence Interval	P
Stone masonry	38	415	12 8 (53)	1.0		
Precast concrete panel	2	40	47.5 (19)	3.7	2 46 – 5 61	< .01
Precast concrete frame	8	577	87.0 (502)	6.8	5.29 – 8 78	< .01
Total	48	1,032	55.6 (574)			

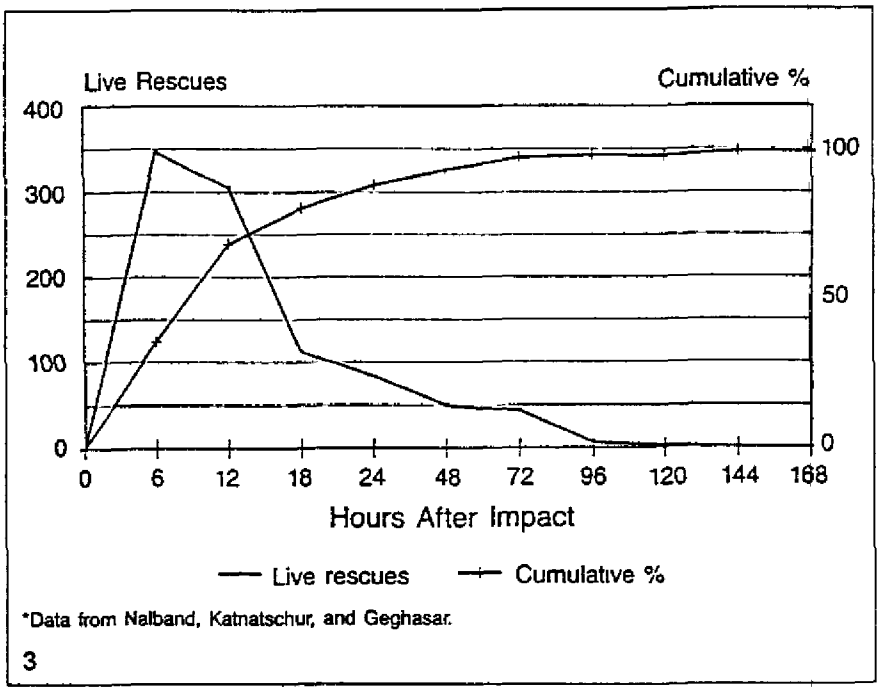

FIGURE 3. *Live rescues as a function of time after impact (total numbers and cumulative percentage).*

ings performed most poorly in terms of number of complete and partial collapses.

According to statistics collected by the Armenian Ministry of Internal Affairs and the State Committee for Construction, most of the fatalities occurred in the collapse of these stone masonry buildings (Table 2). Precast-concrete frame type buildings, however, were associated with highest mortality per building. Detailed statistics were available for eight buildings of this type in Nalband. Eighty-seven percent of the occupants were killed (Table 2). The risk of death was 6 8 times greater in these eight frame buildings than in stone masonry buildings based on this limited sample ($P < .01$). In the sample of precast frame buildings, two of the structures that collapsed resulted in an exceptionally high rate of mortality. One was a sewing factory with 212 workers, of whom 205 (97%) died. The other was a school with 302 children, of whom 285 (94%) died. The precast-concrete panel buildings were also more lethal than the stone masonry structures ($P < .01$).

Of 240 patients reported by the Ministry of Health to be evacuated from the three towns, 23 (9.6%) developed crush syndrome as a result of limb compression, and 11 (4.6%) developed secondary acute renal failure requiring renal dialysis. All evacuated patients were reported to suffer from varying degrees of hypothermia. Postmortem examinations of eight victims removed from the site of a building collapse revealed large amounts of dust in the nasal cavities, throat, and respiratory passages of these victims, suggesting that airway obstruction and asphyxiation from dust were the causes of death. This forensic evidence was corroborated by interviews with local residents of Nalband, who described large and dense dust clouds created by pulverization of the stone and concrete walls of falling buildings.

Data collected 14 days after the earthquake on 4,832 patients admitted throughout hospitals in Armenia (Table 3) showed that combination injuries constituted 1,918 (39.7%) of the cases. Superficial trauma such as lacerations and contusions were the most frequently observed (24.9%), followed by head injuries (22%), lower-extremity injuries (19%), crush syndrome (11%), and upper-extremity trauma (10%).

Search and Rescue

Rescue work was most difficult during the first night when electricity and lights were unavailable; these efforts had to be halted at several locations until the next morning. Operations in these three towns were complicated by absence of street markings, maps, and building plans. Destroyed villages and small towns were isolated by numerous landslides and impassable roads, which delayed relief teams and prevented full knowledge of the extent of the disaster from reaching the authorities. Most of the initial rescue work and medical relief was carried out entirely by local inhabitants. Of the 240 trapped victims who were evacuated for medical care in Yerevan, local Civil Defense workers reported that 228 (95%) were extricated by inhabi-

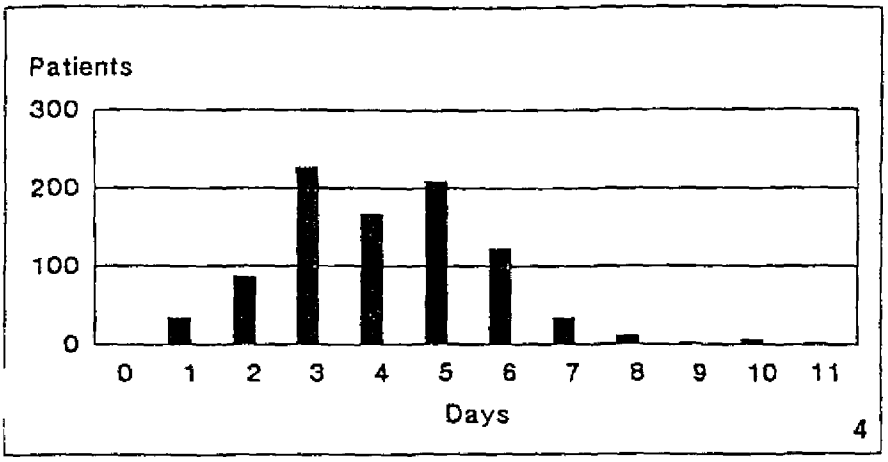

FIGURE 4. *Patients presenting for emergency care at Erebuni Hospital in Yerevan.*

TABLE 3. *Distribution of hospitalized injuries by site as reported to the Ministry of Health of Armenia after the December 7, 1988, earthquake*

Injury	N	%
Head or face	1,040	22.0
Skull, facial fractures	130	2.7
Brain concussion	417	8.6
Other internal head trauma	173	3.6
Open head or facial wounds	320	6 6
Upper extremities	475	10.0
Upper-extermity fractures	265	5 5
Traumatic amputations, arms	197	4 1
Elective amputation, arms	13	0.3
Lower extremities	915	19 0
Lower-extremity fractures	584	12.1
Open wounds, legs	102	2 1
Traumatic amputations, legs	170	3.6
Elective amputation, legs	59	1.2
Superficial trauma	1,203	24.9
Crush syndrome	533	11.0
Other	633	13.1

tants of the three villages themselves. The most sophisticated means of extrication used were hands, shovels, picks, and farming tools

External assistance did not arrive in Nalband for the first 24 hours, and Katnatschur and Geghasar did not receive aid until days 3 and 4, respectively. The first outside relief consisted of military and civil defense units stationed nearby, followed a few days later by volunteer teams from less-affected areas. Heavy rescue equipment such as cranes and bulldozers did not arrive in Nalband until day 5. An operations headquarters was not established in Nalband until December 18, 11 days after the earthquake.

According to information provided by the local army command center in Nalband, the great majority of those rescued alive from collapsed buildings (89%) were extricated during the first 24 hours (Figure 3). The probability of being extricated alive from the debris declined sharply over time. There were no live rescues after day 6.

Emergency Medical Care

Many of the surviving injured victims (30%) received no on-site medical assistance. No individuals were known to have received any advanced on-site medical care, such as cervical-spine immobilization, administration of oxygen or IV fluids, or tracheal intubation. Most of the patients were transported in private vehicles with no in-transit advanced medical care. Because all of the hospitals in the region were severely damaged and many medical personnel were either killed or injured (estimated to be 80%), 311 of the injured (25%) were transported to hospitals in unaffected parts of Armenia or to neighboring Soviet Georgia (information provided by Ministry of Health). Unfortunately, winter weather conditions hampered aeromedical evacuation of the injured. Damage to railways, extraordinary traffic congestion, and impassable roads due to mud made ground evacuation difficult. Ground transport times to receiving hospitals in Yerevan, 75 km away, were often as long as five hours.

In Yerevan, several hospitals admitted a large number of casualties in the days immediately following the earthquake. Erebuni Hospital, a 1,000-bed facility in Yerevan, treated 902 patients in the first 11 days after the earthquake, 80% of whom were admitted during the first five days (Figure 4). Only 22 of the 902 patients (2.4%) requiring hospitalization at Erebuni Hospital as a consequence of the earthquake were admitted seven or more days after the impact.

DISCUSSION

Although the risk of catastrophic earthquakes is widely recognized in parts of California, few people realize that in the past 300 years, the eastern

United States has suffered eight earthquakes of similar or greater magnitude than that in Armenia. There is a high probability that a major earthquake will hit the eastern United States in the next several decades. Building damage and life loss in such an event is predicted to be serious and widespread due to lack of seismic codes and absence of earthquake preparedness programs. Other states, such as Utah and Washington, are also at risk from earthquakes, and despite recognition of the threat, mitigation activities in these areas are inadequate.

Past studies have stressed the importance of critically analyzing earthquakes to develop methods of rapidly assessing health-care needs and improving disaster relief.[15] Epidemiologic studies on earthquake-related injuries have indicated that a quantitative relationship may exist between morbidity and mortality.[16,17] For example, in the Guatemala and Nicaragua earthquakes, the ratio of injured to dead was 3:1. In the area of Armenia studied here, this ratio was reversed, that is, three dead for every person injured. This suggests the extraordinary lethality of the Armenian event.

The Armenian earthquake was of lesser magnitude than the 1989 Loma Prieta earthquake in California. However, its consequences were incomparably greater, primarily because of the design and quality of construction of buildings in the area. The primary cause of death, injury, and destruction was the total collapse of buildings that were not adequately designed for earthquake resistance.

Past studies have shown that factors determining the number of people killed after a building collapses include entrapment, severity of their injuries, how long they can survive without medical attention, and time to rescue and medical treatment.[18-20] A 1977 study on the Guatemala earthquake concluded that deaths and injuries are critically dependent on housing damage and construction materials used.[21] Results reported in our study carry this concept further by suggesting that different building types and structural systems have different collapse mechanisms and patterns of cavity formation when they fail under the influence of earthquake ground motion. The limited survey of three building types in Nalband (eg, stone masonry, precast-concrete panel, and precast-concrete frame) showed death rates of 12%, 46%, and 87%, respectively, suggesting that the type of building and collapse pattern affect survival rates (Table 2).

Infill masonry, panels, and bricks often fell off, killing persons both inside and outside, and the frequent collapse of stairways made it particularly difficult for people to escape because many of these buildings had only one stairway. In all three building types, the collapse of nonstructural elements such as parapets caused many serious injuries. The total collapse ("disintegration") of the precast-concrete frame buildings was associated with particularly high mortality rates (more than 90%) because the characteristic failure pattern of this type of construction greatly complicated the search and rescue effort and reduced significantly the opportunity for occupant survival.

We observed that the fragmentation of the floor system resulted in very tight packing of the rubble with no cavities or "void spaces" for possible survival of victims. The distribution and amount of void space in the collapsed structure and the most likely locations of those voids are important in locating and rescuing trapped people quickly. Such information may help to guide future search and rescue operations by pointing out those collapsed buildings that have the greatest probability of containing survivors and by indicating the location of likely void spaces.

As might be expected, entrapment appears to be the single most significant factor associated with death or injury. Death rates were 67-fold and injury rates more than 11-fold those for trapped than nontrapped people. Death rates for those inside greatly exceeded those for persons outside; more than 80% of those trapped died.

This earthquake substantiated that response time for search and rescue is absolutely critical. Our observation that the proportion of people found alive declined with increasing delay in extrication parallels the observations made in Italy after the Campania-Irpinia earthquake in 1980[22,23] and the Tangshan earthquake in 1976.[24] In the Italian study, a survey of 3,619 survivors showed that 93% of those who were trapped and survived were extricated within the first 24 hours. As suggested by our data, if any significant reduction in earthquake mortality is to be achieved, attention should be given to appropriate search and rescue action within the first two days after the impact.

In the Italian study cited above, 95% of the deaths recorded were among those trapped in rubble who died before extrication.[22] Estimates of survivability among entrapped victims buried under collapsed earthen buildings in Turkey and China indicate that within two to six hours, less than 50% of those buried are still alive.[22,23] Although it is not possible to determine whether a trapped person died immediately or survived for some time under the debris, it is undoubtedly true that more people might have been saved if they had been extricated sooner. Safar, studying the 1980 earthquake in Italy,[25] concluded that 25% to 50% of victims who were injured and died slowly could have been saved if initial life-saving first aid had been rendered immediately.

There were major problems with extrication of trapped victims because of lack of adequate equipment and trained rescue personnel. Penetrating concrete slabs and cutting through columns and beams of the precast-concrete frame buildings proved to be major obstacles in the local rescue effort. No cutting tools were available, and the tools that were available proved to be ineffective. The number of people available to help rescue others was greatly reduced because of the very high percentage of people trapped and killed. This scarcity of rescue workers may have contributed to the excessively high mortality in the three towns examined. Most of the search and rescue effort was late and, even at the peak of activity, was seriously inadequate.

In the three towns visited during our reconnaissance mission, very little in the way of basic medical care was administered to persons who had been located and were actively being extricated from the debris. The provision of basic supportive care, such as IV fluids, might have gone a long way toward reducing morbidity and mortality, particularly in preventing the

development of crush syndrome.[26-29]

As with all field surveys after disasters, there were methodological limitations to this study due to chaotic postearthquake conditions. Accordingly, results must be approached with caution. The difficulties encountered in collecting information in our study point out the great need to develop improved survey sampling methods for immediate postdisaster investigations. Much of the data on building damage, location of entrapment, details of victim location and extrication process, and on-site medical care are considered "perishable"[30] and thus lost unless collected very early. Despite the shortcomings of this study, these preliminary observations are striking. Case studies of earthquakes such as described here can suggest hypotheses for future in-depth analysis using more sophisticated epidemiologic methods.[31]

CONCLUSION

The December 7, 1988, Armenian earthquake was one of the most lethal in the 20th century. Major medical problems resulted not only from the direct crushing effects of collapsing buildings but also from severe cold and exposure, prolonged entrapment, delayed medical care, and long transportation times to the nearest unaffected hospitals. Follow-up studies that analyze the complex relationship among factors related to survival as detailed here should provide further insights that will lead to the improvement of future rescue efforts.

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