The Importance of Evidence-Based Disaster Planning

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Disaster planning is only as good as the assumptions on which it is based. However, some of these assumptions are derived from a conventional wisdom that is at variance with empirical field disaster research studies. Knowledge of disaster research findings might help planners avoid common disaster management pitfalls, thereby improving disaster response planning. To illustrate the point, this article examines several common assumptions about disasters, compares them with research findings, and discusses the implications for planning. These assumptions are that:

1. Dispatchers will hear of the disaster and send emergency response units to the scene.
2. Trained emergency personnel will carry out field search and rescue.
3. Trained emergency medical services personnel will carry out triage, provide first aid or stabilizing medical care, and—if necessary—decontaminate casualties before patient transport.
4. Casualties will be transported to hospitals by ambulance.
5. Casualties will be transported to hospitals appropriate for their needs and in such a manner that no hospitals receive a disproportionate number.
6. Authorities at the scene will ensure that area hospitals are promptly notified of the disaster and the numbers, types, and severities of casualties to be transported to them.
7. The most serious casualties will be the first to be transported to hospitals.

The current status and limitations of disaster research are discussed, and potential interventions to response problems are offered that may be of help to planners and practitioners and that may serve as hypotheses for future research. [Ann Emerg Med. 2006;47:34-49.]

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INTRODUCTION

Numerous responders and planners who have been involved in disaster events have written articles reporting lessons learned in these events. A review of this literature, however, shows that many of the problems experienced in planning and responding to disasters seem to be "learned" over and over again in disaster after disaster. Although the reasons for this are complex, a significant contributing factor is that disaster planning is only as good as the assumptions on which it is based. Knowledge based on systematically collected data from field disaster research studies might help planners avoid common disaster management pitfalls, thereby improving disaster response planning. The focus of this article is on research dealing with operational and organizational emergency medical response issues in domestic, peacetime disasters.

Limitations of Disaster Research

Although there are many limitations on current research about disaster medical planning, many data have been gathered that can be used to improve emergency planning. The status and limitations of current research include the following:

- Most operational research on disaster medical planning has been conducted on sudden, single-impact disasters such as tornadoes, flash floods, or explosions.[1] In these sudden-onset events, the researcher usually cannot select the location where the data collection will occur.[2]
- The selection of variables that can be controlled is often limited.[2] The unexpected nature of disasters also means that data collection on emergency medical responses generally has to be retrospective.[2] This, in turn, creates difficulties with before-and-after comparisons of the event. For example, persons in the locality before the disaster may have relocated because of destruction of their homes and workplaces. Others will have been in the area only temporarily because of the disaster (eg, assigned or volunteer responders).[2] This makes probability sampling challenging.[1]
- Data are often evanescent, which is the case for a number of reasons; for example, individuals and officials are often more willing to share information in the immediate aftermath of a disaster than later.[3] Many of those affected will be in the

Table. Common disaster planning assumptions versus research observations.

Assumption Number	Research Observation	Planning Implications	Potential Interventions
1 Dispatchers will hear of the disaster and send emergency response units to the scene.	Emergency response units, both local and distant, will often self-dispatch.	Effective disaster planning requires planning not only for the jurisdiction but also at the intercommunity level. Plans should anticipate the likelihood that more help than needed will arrive, whether requested or not.	Expect unsolicited responders and develop a plan for coordinating them. Establish intercommunity or statewide mutual aid plans and training. Use staging or check-in areas outside of rapidly established security perimeters.
2 Trained emergency personnel will carry out field search and rescue.	Most initial search and rescue is carried out by the survivors themselves.	Planners may incorrectly assume that they will have control over disaster EMS responses. Disaster search and rescue is often ad hoc and uncoordinated. Even if not part of the planned response, law enforcement officers often become involved in search and rescue. Survivors involved in search and rescue may have the best information on the location of the missing.	Train first responders (including law enforcement officers) how to coordinate with survivors carrying out search and rescue. Designate personnel to obtain information from survivors about the location of the missing.
3 Trained EMS personnel will carry out triage, provide first aid or stabilizing medical care, and—if necessary—decontaminate casualties before patient transport.	Casualties are likely to bypass on-site triage, first-aid, and decontamination stations and go directly to hospitals.	Hospitals should not assume that casualties will be triaged, decontaminated, or given first aid in the field. Patients arriving in private cars may need to be carefully extricated so that injuries are not aggravated.	Develop real-time instructions that can be given to survivors (eg, by commercial radio) on how to: protect themselves; give first aid; deal with contaminated casualties. Provide courses on first aid, search and rescue, and disaster care for the public. Send first responders to hospitals to extricate casualties from private vehicles.
4 Casualties will be transported to hospitals by ambulance.	Most casualties are not transported by ambulance. Rather, they arrive at hospitals by a variety of nonambulance vehicles (eg, private cars, police vehicles, buses, taxis, or even on foot).	EMS authorities often have little control over time of transport or hospital destination for disaster casualties. Transport outside of the EMS system also poses challenges for patient tracking.	Educate the public about precautions to take when transporting casualties and about which should not be moved. Establish procedures for collecting information after the fact from hospitals about what casualties they have received.
5 Casualties will be transported to hospitals appropriate for their needs and in such a manner that no hospitals receive a disproportionate number.	Most casualties are transported to the closest or most familiar hospitals.	Although specific hospitals may be designated to receive contaminated casualties (eg, as required by Superfund Amendments and Reauthorization Act Title III), it is the patients who will often choose their destination. Thus, all hospitals must be prepared to do decontamination. Although it may not be possible to prevent inefficient casualty distribution, it may be possible to influence or plan around it.	Consider having ambulances bypass hospitals closest to the disaster. Establish area and intercommunity EMS/hospital mutual aid plans and radio systems so that ambulances can be directed to hospitals best able to treat their patients. Use a "First-Wave" protocol to divide initial casualties among area hospitals.

However, when more help arrives than requested or expected, they may not have set up effective processes for integrating them into the response.[62]

Potential Interventions for Self-Dispatched Responders

As illustrated in the examples above, disaster planners and public safety agencies need to expect unsolicited responders and have a plan for coordinating or directing their activities.

Managing outside responders could be facilitated by the establishment of an intercommunity or statewide mutual aid plan (for example, one based on the Incident Command System) and intercommunity or statewide mutual aid radio frequencies and procedures. Inclusion of agreements on who is responsible for collecting specific types of information (such as estimates of casualties, damage assessments, resource needs assessments, and resource availability), who needs to receive the information, and the technical means for transmitting the information to those who need it might help address the problem.

- Example: Terrorist attack on the Pentagon in Washington, DC, September 11, 2001. "Effective inter-organizational coordination was a key factor in the successful response to the attack on the Pentagon.... Officials of the Metropolitan Washington Council of Governments, composed of 17 regional jurisdictions, and key Federal Government agencies were involved in hourly conversations and briefings about the situation at the Pentagon from the morning of September 11. The command centers of the local jurisdictions worked smoothly with each other since their emergency plans had been exercised during their preparation efforts for the Year 2000 computer concerns two years earlier. More importantly, the mutual aid agreements with the Fire and Rescue units from Arlington County, Fairfax County, Montgomery County, Alexandria, and Washington, DC following the Air Florida Flight 90 crash of January 13, 1982 had produced a common doctrine and a shared working experience. The other county responders recognized that Arlington County was in the lead position and were able to efficiently integrate their resources in the ACFD [Arlington County Fire Department] incident command system.... The basis for the on scene structure was the Incident Command System [ICS]. Arlington County uses ICS on a daily basis for all fire events, even for small fires. Personnel responding to the Pentagon attack were, therefore, integrated into a familiar operational structure." This integration was further promoted by the establishment and maintenance of 2-way radio communications among the responding agences.[69]

Although mutual aid procedures have been suggested as an important tool for integrating outside responders, larger cities sometimes neglect to develop such procedures because city resources are so great that they do not anticipate the need for outside assistance.

- Example: Riots, Los Angeles, CA, 1992. "LAPD [Los Angeles Police Department] has, for many years, avoided mutual aid arrangements, whereby law enforcement from one jurisdiction agrees to assist law enforcement in another jurisdiction, believing that it was more likely that the Department would be called upon to help others than be in need of help itself.... The LAPD and the City had not engaged in effective inter-agency planning and training with other mutual aid providers so that the LAPD and the City would be prepared to utilize mutual aid resources quickly and effectively in the event of widespread civil disorder."[70,71]

The expeditious use of security perimeters and staging or check-in areas could help to improve coordination among local and outside responders (Figure 1). Establishing these perimeters requires the cooperation of law enforcement agencies to rapidly close off the area with roadblocks and portable barricades and fences. All incoming emergency responders are diverted to staging ("immediate availability") or check-in ("standby") areas outside the affected zone. At these areas are check-in or staging area managers in direct radio contact with the multiagency on-scene command post. This approach has several advantages. First, it may allow a rapid inventory of incoming assets, including those who have responded on an unsolicited basis. Second, incoming responders can be provided with a face-to-face briefing (which reduces radio traffic) and then provided with a radio frequency (or a radio) and a task assignment as directed by incident command. Third, this approach allows the scene to be restricted only to those currently needed there while keeping close at hand resources that might subsequently be needed. It should be noted that, although *rapid* establishment of security perimeters may be possible in smaller, localized disasters, this may not be possible in sudden-onset, large-scale, geographically dispersed events (eg, earthquakes).

ASSUMPTION 2: TRAINED EMERGENCY PERSONNEL WILL CARRY OUT FIELD TRIAGE. RESEARCH OBSERVATION: THE SURVIVORS THEMSELVES CARRY OUT MOST OF THE INITIAL SEARCH AND RESCUE.

Studies of search and rescue in disasters have shown that a substantial proportion of, if not most, search and rescue is carried out by untrained survivors.[8,10,17,24,26,27,37,39,72-83]

- Example: Earthquake, San Francisco Bay Area, 1989. A random household survey of residents in 2 of the 6 counties impacted by the earthquake showed that 3% of the residents of San Francisco County and 5% of the residents of Santa Cruz County became involved in postimpact search and rescue, which adds up to more than 31,000 persons.[84]
- Example: Earthquake, Mexico City, 1985. More than 2.8 million adults provided volunteer assistance in the aftermath of the earthquake, and more than 1.2 million participated in volunteer search and rescue activities.[85]

Despite the best efforts and planning, it is hard to envision how anyone arriving in the affected area of one of these disasters could gain command and control over the massive search and rescue efforts carried out by the survivors, especially in the early hours after impact.

ASSUMPTION 3: TRAINED EMS PERSONNEL WILL CARRY OUT TRIAGE, PROVIDE FIRST AID OR STABILIZING MEDICAL CARE, AND—IF NECESSARY—DECONTAMINATE CASUALTIES BEFORE PATIENT TRANSPORT. RESEARCH OBSERVATION: CASUALTIES ARE LIKELY TO BYPASS ON-SITE TRIAGE, FIRST AID, AND DECONTAMINATION STATIONS AND GO DIRECTLY TO HOSPITALS.

Although disaster plans may call for casualties to be triaged and given lifesaving first aid in the field, survivors often bypass field first aid and triage efforts[9,80,93,94] because they may not know that field first aid or triage stations exist, much less where they are.[9,95] In addition, survivors may consider these stations as a lower level of care than that available at hospitals.[9]

Although there are limited data on hazardous materials disasters, it is possible that decontamination stations set up in the field for hazardous materials disasters would also be bypassed. In a series of 12 case studies of nondisaster chemical and biologic incidents that Vogt and Sorensen carried out from 1999 to 2001, patients in 3 of the incidents were transported to hospitals without having been first decontaminated.[96] A report by Berkowitz et al on multicasualty incidents involving hazardous materials spills between 1993 and 2000 stated that 33.1% of those decontaminated were not decontaminated in the field.[97]

- Example: Sarin attack, Tokyo, Japan, 1995. At the time of the sarin attack, the Tokyo Metropolitan Fire Department had its own triage tags, but these were not used for the majority of the victims, who went to hospitals without the aid of fire department ambulances. Also, there was no field decontamination of victims at the disaster site.[98]
- Example: Earthquake, Coalinga, CA, 1983. In accordance with the local disaster plan, a physician set up a triage area in the most devastated part of town. However, 31 of the 38 casualties arriving at the hospital in the first hour came by private car or on foot, the most serious in the back of a local neurosurgeon's pickup truck. All of the casualties completely bypassed the triage area and went directly to the hospital.[63,64]

Planning Implications of Lack of On-Site Triage, First Aid, and Decontamination

Hospital personnel should be prepared to carry out triage and decontamination at the ED entrance or redirect disaster victims from there to other areas at the hospital for such care. They should also not assume that contaminated casualties will be decontaminated in the field.

Injured victims may arrive in private cars and need to be provided with immediate first aid or medical care and stabilized (eg, on a spine board) before they are extricated from these vehicles. It is of interest to note that the likelihood may be that those with the most experience and training in extricating victims from vehicles may be those at the scene (eg, firefighters and emergency medical technicians).

Potential Interventions

Local health authorities may wish to consider developing simple instructions to give to members of the public who become involved in on-site search and rescue. These instructions could be conveyed by a number of means (eg, by local radio stations, Amber Alert systems, the Emergency Alert System (http://www.fcc.gov/cgb/consumerfacts/eas.html) or by the first arriving authorities on the scene). Instructions to these persons might include simple directions for protecting themselves, giving first aid, or dealing with contaminated casualties.

Efforts to educate the public about basic first aid, search and rescue, and disaster care (eg, through high school courses or Citizens Corps Programs, http://www.citizencorps.gov) might help improve the on-site care of those rescued by survivor-volunteers.

Disaster planners may want to consider dispatching some of the available extrication-trained personnel directly to hospitals, rather than to the scene, so they can assist in extricating casualties from private vehicles, and can interview survivors to obtain information on the location of other missing casualties.

ASSUMPTION 4: CASUALTIES WILL BE TRANSPORTED TO HOSPITALS BY AMBULANCE. RESEARCH OBSERVATION: MOST CASUALTIES ARE NOT TRANSPORTED BY AMBULANCE; RATHER, THEY ARRIVE AT HOSPITALS BY A VARIETY OF NONAMBULANCE VEHICLES (EG, PRIVATE CARS, POLICE VEHICLES, BUSES, TAXIS, OR EVEN ON FOOT).

For many untrained persons who become involved in search and rescue at a disaster site, the "best emergency care" is seen as transport to the closest hospital as quickly as possible. If ambulances are not promptly available, survivors do not tend to wait for their arrival but will use the most expedient means to transport the casualties.[11,13] The Disaster Research Center study ascertained that the *initial* means of casualty arrival at 75 hospitals for which data were available was as follows:

- ambulance, 54%
- private car, 16%
- police car, 6%
- helicopter, 5%
- bus or taxi, 5%
- on foot, 4%, and
- undetermined, 10%.

These figures describe only the *initial* means of casualty transport to hospitals: overall, most casualties were not transported by ambulance.[9] Other reports also seem to indicate that many, if not most, disaster casualties are transported to hospitals by means other than ambulance.[14,17,26,27,43,51,54,61,63,64,76,78,80,81,88,93,99-108]

- Example: Loma Prieta earthquake, San Francisco Bay Area, 1989. For 1,774 patients for whom data were available (out of 2,390 cases), 26% of earthquake-related emergency cases

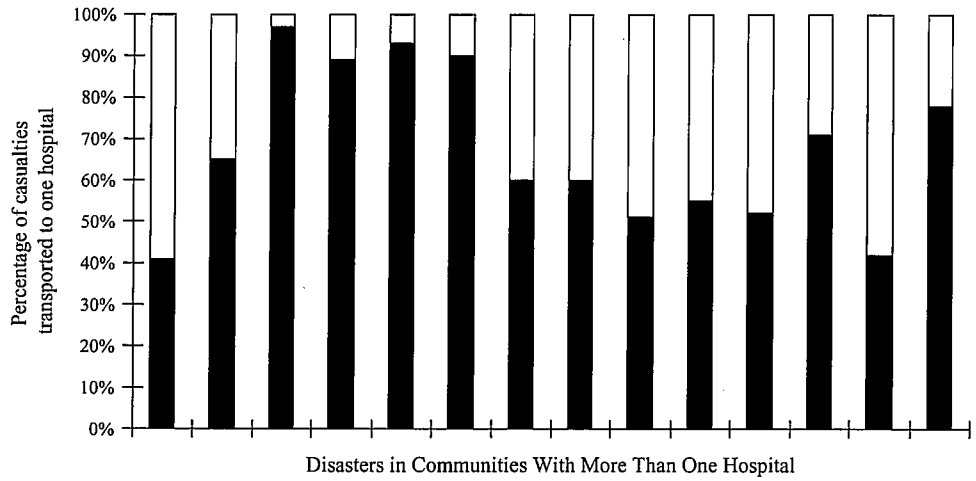

Figure 2. The Disaster Research Center Study: the percentage of casualties transported to one hospital. Of the 29 disasters in the study, 14 are included on this chart; the 15 communities with only 1 hospital were excluded.[14]

victims, regardless of legislative mandates and local planning arrangements. Although it is unlikely that any planning will prevent inefficient casualty distribution, there may be ways to influence it or plan around it.

Potential Interventions

Even though the majority of casualties are transported by private vehicle and completely outside the EMS system, an opportunity exists to balance casualty flow by controlling the destinations of the minority of casualties transported by ambulances under control of the local EMS system. For example, given the availability of multiple hospitals in an affected community, it might be best to have ambulances try to avoid the hospital closest to the disaster site. Control of ambulance destinations is difficult in the absence of a functioning 2-way radio system that can link all ambulances (regardless of jurisdiction) to a single dispatch center. This system functions best when it has the ability to contact local ambulances and those coming from outside the area. Finally, appropriate coordination of ambulance destination might be facilitated by an area-wide medical/hospital mutual aid radio communication system. Such a system might make it easier to determine which hospitals are able to receive casualties, which hospitals are damaged or being evacuated, and which hospitals are being overloaded with patients. Disaster plans that rely on telephones or cellular phones to carry out this coordination are likely destined for failure. Even if telephone and cellular circuits are undamaged, they tend to become rapidly overloaded, leading to circuit shutdown.[50]

Another approach might be to predetermine how many casualties each hospital will initially be sent. Such a plan can be implemented even before hospitals can be contacted for information on their patient-receiving capacity. One such system, the "First-Wave Protocol," has been previously described.[22] Each hospital determines in advance how many patients in each triage category it could take care of in a disaster when there is a minimum of staff available (for example, at 2 AM on a Saturday). This is called the First Wave Score. For a given triage category, each hospital divides its own First Wave Score by the sum of all the first waves scores for all the area hospitals for that triage category. This is expressed as a percentage and is called the First Wave Ratio. If, for example, Mercy Hospital determines that it could handle 4 patients in the "critical" triage category, and all of the area hospitals could handle together a total of 40 "critical" patients, then Mercy Hospital would have a "Critical" First Wave Ratio of 10% (4 of 40). In a disaster, the goal would be to send approximately 10% of the initial casualties triaged as "Critical" to Mercy Hospital. Similarly, each hospital would determine First Wave Ratios for each triage category. Subsequently, a hospital polling process could be used to determine more accurately each hospital's capacity on a moment-by-moment basis.

Authorities might also be able to curtail overloading of the closest hospital by advising survivors at the scene that the wait times in more distant EDs are likely to be shorter and by providing preprinted maps with directions to local hospitals. Finally, it might be possible to set up triage areas on major roads leading to the closest hospitals so that patients could be redirected to the hospitals most appropriate for their needs.

ASSUMPTION 6: AUTHORITIES AT THE FIELD WILL ENSURE THAT AREA HOSPITALS ARE PROMPTLY NOTIFIED OF THE DISASTER AND THE NUMBERS, TYPES, AND SEVERITIES OF CASUALTIES TO BE TRANSPORTED TO THEM. RESEARCH OBSERVATION: HOSPITAL NOTIFICATION OF A DISASTER MAY BE FROM THE FIRST ARRIVING VICTIMS OR THE NEWS MEDIA, RATHER THAN FROM AUTHORITIES IN THE FIELD. OFTEN, INFORMATION AND UPDATES ABOUT INCOMING CASUALTIES ARE INSUFFICIENT OR LACKING.

To the extent that hospitals can be forewarned before casualty arrival, they can better organize the resources necessary

ASSUMPTION 7: THE MOST SERIOUS CASUALTIES WILL BE THE FIRST TO BE TRANSPORTED TO HOSPITALS. RESEARCH OBSERVATION: THE LEAST SERIOUS CASUALTIES OFTEN ARRIVE FIRST.

The Disaster Research Center Study observed what one might call "reverse-triage," with the least serious casualties tending to arrive first.[9,11,12,14,113] Similar observations were reported in the 1989 San Francisco earthquake[130] and the 1985 Mexico City earthquake.[131] This could be because the more serious casualties were more likely to be trapped in the rubble, requiring more sophisticated search and rescue efforts to extricate them. Also, the least serious casualties are often more able to extricate and transport themselves.[132]

Implications of the Least Serious Arriving at Hospitals First

Unfortunately, because of the lack of timely information from the field, hospitals sometimes may be unaware that the more serious cases are yet to come, which has caused problems when the hospital's ED beds were already occupied by earlier arriving, less serious casualties.[11]

Potential Interventions

To the extent possible, authorities in the field should communicate with hospitals to advise them about casualty numbers and severities. This, of course, would seem more likely to occur if an existing EMS-hospital radio network is functioning and if EMS disaster planning makes it clear who at the site has overall responsibility for this task. Even then, hospital planners should realize that gathering and transmitting this information is often difficult and may not always occur.

At the same time, hospital staff might be advised as a general precaution to hold beds for serious casualties in reserve and not fill them with minor casualties until it is certain that those with more serious conditions have all been transported.

Suggestions for Future Research

Comparative systematic studies of EMS and emergency health care across multiple disasters, such as the Disaster Research Center Study,[9,11-17] need to be repeated to see if the radical changes in EMS and health care have altered the patterns observed in the late 1970s.

A sustainable funding mechanism is needed to promote field studies of operational emergency health and medical care responses in disasters.

Field research in this area often involves rapidly evolving disasters. Furthermore, many of the relevant data become less accessible with time. Thus, it is important to establish standing field research teams that can be mobilized quickly after a disaster. Predisaster funding is important so these research teams can develop a standby capability and develop standardized data collection procedures and instruments that can be implemented in successive events.

More emphasis needs to be placed on reporting the findings of field research through peer-reviewed scientific journals. Although this does occur, there are important findings published in non–peer-reviewed or unpublished reports that would be more credible if peer reviewed. Where available, the research instruments (eg, survey questionnaires) should also be reported, and efforts should be expended to develop standardized questionnaires for use by other researchers so that a uniform body of comparable data can evolve.

Methodology involved in quantitative estimates (eg, such as those for proportions of patients transported by ambulances) needs to be more consistently reported.

Research effort needs to be expended to study the effectiveness of various intervention strategies that hold promise for addressing some of the response problems identified in descriptive disaster studies. Some potential interventions have been identified in this article.

The question of whether various preparedness and response measures actually affect morbidity and mortality remains to be addressed. This is a challenging area that should be a greater focus of future research.

When such measures are identified, they could be used to assess the status of local disaster readiness through regular, national, random sample surveys. By comparing successive surveys, it could be determined whether preparedness is improving or deteriorating over time.

A national clearinghouse for disaster health and medical research is needed that can collect, collate, analyze, and disseminate research findings. Making these findings available in digital format at no cost to planners and practitioners would help to ensure that they are more often integrated into practice.

Summary

It is important for local communities to plan and train for disasters. However, planning and training are not enough: one must plan for the right things. Valuable lessons can be learned from formal disaster research studies. Often disaster plans fail to anticipate common response problems that have been identified during systematic field research studies:

- Emergency response units, both local and distant, will often self-dispatch.
- Most initial search and rescue is carried out by the survivors themselves.
- Casualties are likely to bypass on-site triage, first-aid, and decontamination stations and go directly to hospitals.
- Most casualties are not transported by ambulance. Rather, they arrive at hospitals by a variety of nonambulance vehicles (eg, private cars, police vehicles, buses, taxis, or even on foot).
- Most casualties are transported to the closest or most familiar hospitals.
- Hospital notification of a disaster may be from the first arriving victims or the news media, rather than from authorities from the scene. Often information and updates about incoming casualties are insufficient or lacking.
- The least serious casualties often arrive first.

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5. *Disasters: The Journal of Disaster Studies, Policy and Management.* Oxford, UK: Blackwell Publishers. Available at: www.blackwellpublishing.com/journal.asp?ref=0361-3666.
6. *International Journal of Mass Emergencies and Disasters.* Los Angeles: University of Southern California. Telephone: (213) 740-6842; E-mail: ijmed@usc.edu; Available at: http://www.usc.edu/schools/sppd/ijmed.
7. *Morbidity and Mortality Weekly Report.* Centers for Disease Control and Prevention. Available at: http://www.cdc.gov/mmwr.
8. Natural Hazards Center at the University of Colorado. Includes links to the Natural Hazards Observer and Disaster Research newsletters. Boulder, CO: University of Colorado. Telephone: (303) 492-6819; E-mail: hazctr@spot.colorado.edu: Available at: http://www.colorado.edu/hazards.
9. Pan American Health Organization (PAHO), Emergency Preparedness and Disaster Relief Coordination Program. Available at: http://paho.org/English/DD/PED/home.htm.
10. Regional Disaster Information Center (CRID) for Latin America and the Caribbean. San Jose, Costa Rica: Regional Disaster Information Center for Latin America and the Caribbean. Available at: http://www.crid.or.cr/crid/Indexen.htm.

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REFERENCES

1. Killian LM. An introduction to methodological problems of field studies in disasters. In: Stallings RA, ed. *Methods of Disaster Research.* Philadelphia, PA: Xlibris; 2002:21-49.
2. Killian LM. *An Introduction to Methodological Problems of Field Studies in Disasters, Publication 465.* Washington, DC: Committee on Disaster Studies, National Academy of Sciences, National Research Council; 1956.
3. Quarantelli E. The Disaster Research Center field studies of organized behavior in the crisis time period of disasters. *Int J Mass Emerg Disasters.* 1997;15:47-69.
4. Bourque LB, Shoaf KI, Nguyen LH. Survey Research. *Int J Mass Emerg Disasters.* 1997;15:71-101.
5. Quarantelli EL. The Disaster Research Center (DRC) field studies of organized behavior in the crisis time period of disasters. In: Stallings RA, ed. *Methods of Disaster Research.* Philadelphia, PA: Xlibris; 2002:94-126.
6. McKinsey & Company. The McKinsey report: increasing FDNY's preparedness [McKinsey & Company Web site]. Available at: http://www.nyc.gov/htm/fdny/html/mck_report/toc.shtml. Accessed August 30, 2002.
7. Kerns DE, Anderson PB. EMS response to a major aircraft incident: Sioux City, Iowa. *Prehospital Disaster Med.* 1990; 5:159-166.
8. Oakland Fire Department. *Oakland Fire Department Earthquake Report.* Oakland, CA: City of Oakland, California, Fire Department; 1990.
9. Quarantelli EL. *Delivery of Emergency Medical Care in Disasters: Assumptions and Realities.* New York, NY: Irvington Publishers, Inc; 1983.
10. Tierney KJ, Lindell MK, Perry RW. *Facing the Unexpected: Disaster Preparedness and Response in the United States.* Washington, DC: Joseph Henry Press; 2001.
11. Tierney KJ, Taylor VA. EMS delivery in mass emergencies: preliminary research findings. *Mass Emerg.* 1977;2:151-157.
12. Dynes RR. A background note on the preliminary findings and impressions of the DRC studies. *Mass Emerg.* 1977;2:147-150.
13. Worth MF, Stroup J. Some observations of the effect of EMS law on disaster related delivery systems. *Mass Emerg.* 1977;2: 159-168.
14. Golec JA, Gurney PJ. The problem of needs assessment in the delivery of EMS. *Mass Emerg.* 1977;2:169-177.
15. Neff JL. Responsibility for the delivery of emergency medical services in a mass casualty situation: the problem of overlapping jurisdictions. *Mass Emerg.* 1977;2:179-188.
16. Wright JE. The prevalence and effectiveness of centralized medical responses to mass casualty disasters. *Mass Emerg.* 1977;2: 189-194.
17. Tierney K. *Project Summary: Disaster Analysis: Delivery of Emergency Medical Services in Disasters.* Newark, DE: Disaster Research Center, University of Delaware; 1993:190.
18. Pons PT, Cantrill SV. Mass casualty management: a coordinated response. *Crit Decisions Emerg Med.* 2003;17:7-11.
19. Mitchell GW. The triage process. *Top Emerg Med.* 1986;7:34-45.
20. Caroline NL. The multicasualty incident. In: Caroline NL, ed. *Emergency Care in the Streets.* 4th ed. Boston, MA: Little, Brown and Company; 1991:401-410.
21. Wiener SL, Barrett J. Mass casualties and triage. In: Wiener SL, Barrett J, eds. *Trauma Management for Civilian and Military Physicians.* Philadelphia, PA: WB Saunders; 1986:536-549.
22. Auf der Heide E. Disaster Response: Principles of Preparation and Coordination. St. Louis, MO: CV Mosby; 1989. Available,

60. Lewis FR, Trunkey DD, Steele MR. Autopsy of a disaster: the Martinez bus accident. *J Trauma.* 1980;20:861-866.
61. Morris BAP, Armstrong TM. Medical response to a natural disaster: the Barrie tornado. *CMAJ.* 1986;134:767-769.
62. Auf der Heide E. Disaster planning, part II: disaster problems, issues, and challenges identified in the research literature. *Emerg Med Clin North Am.* 1996;14:453-480.
63. Kallsen G. Collapse of Coalinga. *J Emerg Med Serv.* 1983;8: 24-29.
64. Seismic Safety Commission. *Preliminary Reports Submitted to the Seismic Safety Commission on the May 2, 1983 Coalinga Earthquake, Publication No. SSC 83-08.* Sacramento, CA: State of California, Seismic Safety Commission; 1983.
65. Sundberg C. In the fiery aftermath of the crash of Flight 232, Sioux City EMS proved that it has the right stuff. *Emergency.* 1990;22:30-330.
66. Monserrate R. The crash of United Flight 232: rescue, recovery and identification of victims. *Disaster Management.* 1992;4:157-162.
67. Sopher L, Petersen R, Talbott M. The crash of Flight 232: an emergency care perspective. *J Emerg Nurs.* 1990;16:61A-66A.
68. Nordberg M. United Flight 232: the story behind the rescue. *Emerg Med Serv.* 1989;18:15, 22-31.
69. Harrald J, Barbera JA, Renda-Tanali I, et al. *Observing and Documenting Inter-Organizational Response to the September 11th Attack on the Pentagon.* Washington, DC: Institute for Crisis, Disaster, and Risk Management, The George Washington University; 2002.
70. Los Angeles Police Department. *A History of the Los Angeles Earthquake, February 9, 1971.* Los Angeles, CA: Los Angeles Police Department; 1972.
71. Webster WH, Williams H. *The City in Crisis: A Report by the Special Advisor to the Board of Police Commissioners on the Civil Disorder in Los Angeles.* Los Angeles, CA: Office of the Special Advisor to the Board of Police Commissioners City of Los Angeles; 1992.
72. Drabek TE. *Human System Responses to Disaster: An Inventory of Sociological Findings.* New York, NY: Springer-Verlag; 1986.
73. Wenger DE, James TF. The convergence of volunteers in a consensus crisis: the case of the 1985 Mexico City earthquake. In: Dynes R, Tierney KJ, eds. *Disasters, Collective Behavior, and Social Organization.* Newark, DE: University of Delaware Press; 1994:229-243.
74. De Bruycker M, Greco D, Lechat MF. The 1980 earthquake in Southern Italy: morbidity and mortality. *Int J Epidemiol.* 1985; 14:113-117.
75. Angus DC, Pretto EA, Abrams JI, et al. Epidemiologic assessment of mortality, building collapse pattern and medical response after the 1992 earthquake in Turkey. *Prehospital Disaster Med.* 1997;12:222-231.
76. Adams CR. *Search and Rescue Efforts Following the Wichita Falls Tornado, Technical Report No. 4, SAR Research Project, Department of Sociology.* Denver, CO: University of Denver; 1981.
77. Drabek TE. *Emergency Management: The Human Factor.* Washington, DC: Federal Emergency Management Agency National Emergency Training Center; 1985.
78. Guha-Sapir D, Lechat MF. Reducing the impact of natural disasters: why aren't we better prepared? *Health Policy Planning.* 1986;1:118-126.
79. Pangi R. *Consequence Management in the 1995 Sarin Attacks on the Japanese Subway System.* Boston, MA: John F. Kennedy School of Government, Harvard University; 2002. BCSIA discussion paper 2002-4. Available at: http://bcsia.ksg.harvard.edu/publication.cfm?program=CORE&ctype=paper&item_id=138, or http://bcsia.ksg.harvard.edu/BCSIA_content/documents/Consequence_Management_in_the_1995_Sarin_Attacks_on_the_Japanese_Subway_System.pdf
80. Barton A. *Communities in Disaster: A Sociological Analysis of Collective Stress Situations.* Garden City, NY: Doubleday; 1969.
81. Aguirre BE. The social organization of search and rescue: evidence from the Guadalajara gasoline explosion. *Int J Mass Emerg Disasters.* 1995;13:67-92.
82. Roces M, Pastor N, Gopez I, et al. Earthquake disaster: Luzon, Philippines. *MMWR Morb Mortal Wkly Rep.* 1990;39: 573-577.
83. Klain M, Ricci E, Safar P, et al. Disaster reanimatology potentials: a structured interview study in Armenia, I: methodology and preliminary results. *Prehospital Disaster Med.* 1989;4:135-154.
84. O'Brien PW, Mileti DS. Citizen participation in emergency response. In: Bolton P, ed. *The Loma Prieta, California, Earthquake of October 17, 1989: Public Response.* Washington, DC: US Government Printing Office; 1993:B23-B30.
85. Dynes RR, Quarantelli EL, Wenger D. *Individual and Organizational Response to the 1985 Earthquake in Mexico City, Mexico, Book and Monograph Series #24.* Newark, DE: Disaster Research Center, University of Delaware; 1990.
86. Freeman C, Van Ness C, Morales JE. *Hurricane Andrew: Lessons for California.* Sacramento, CA: State of California, Emergency Medical Services Authority; 1993.
87. Governor's Office of Emergency Services. *Law Enforcement Operations Report: Loma Prieta Earthquake.* Sacramento CA: State of California, Governor's Office of Emergency Services Law Enforcement Division; 1990.
88. Kansas City Health Department. *Hyatt Disaster Medical Assessment.* Kansas City, MO: Health Department; 1981.
89. McKinsey & Company. *Improving NYPD Emergency Preparedness and Response.* New York, NY: New York City Police Department; 2002.
90. Barton AH. *Social Organization Under Stress: A Sociological Review of Disaster Studies, Disaster Study No. 17, Publication No. 1032.* Washington, DC: Disaster Research Group, National Academy of Sciences, National Research Council; 1963.
91. Form W, Nosow S. *Community in Disaster.* New York, NY: Harper; 1958.
92. Holloway RM. Operations and planning in multiple casualty incidents. *Mass Emerg.* 1977;2:137-146.
93. Noji ED, Keen GD, Armenian HK. The 1988 earthquake in Soviet Armenia: a case study. *Ann Emerg Med.* 1990;19:891-897.
94. Adamson S. *First Aid Response to the Kobe Earthquake, January 17, 1995.* Boulder, CO: University of Colorado, Natural Hazards Research and Applications Information Center; 1997.
95. Fechtel EJ. How St. Mary's Hospital, Athens, Ga. handled a recent tornado disaster. *Hosp Prog.* 1973;54:38-40.
96. Vogt BM, Sorensen JH. *How Clean Is Safe? Improving the Effectiveness of Decontamination of Structures and People Following Chemical and Biological Incidents.* Oak Ridge, TN: Oak Ridge National Laboratory; 2002. ORNL/TM-2002/178.
97. Berkowitz Z, Horton DK, Kaye WE. Hazardous substances releases causing fatalities and/or people transported to hospitals: rural/agricultural vs. other areas. *Prehospital Disaster Med.* 2004;19:213-220.
98. Okumura T, Suzuki K, Fukuda A, et al. The Tokyo Subway sarin attack: disaster management, part 1: community emergency response. *Acad Emerg Med.* 1998;5:613-617.
99. Arnold C, Durkin M, Eisner R, et al. *Imperial County Services Building: Occupant Behavior and Operational Consequences as a Result of the 1979 Imperial Valley Earthquake.* San Mateo, CA: Building Systems Development, Inc; 1982.
100. Koehler G, Isbell D, Freeman C, et al. *Medical Care for the Injured: The Emergency Medical Response to the April, 1992, Los Angeles*