A Reassessment and Review of the Bam Earthquake Five Years Onward: What Was Done Wrong?

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Keywords: Bam earthquake; earthquake; Iran; management

Abbreviations:
EMS = emergency medical services
PTSD = post-traumatic stress disorder
S&R = Search-and-Rescue

Received: 25 November 2008
Accepted: 22 December 2008
Revised: 30 December 2008

Web publication: 05 October 2009

Abstract

Introduction: An earthquake measuring 6.6 on the Richter scale on 23 December 2003 devastated the city of Bam in southeastern Iran. During the response and recovery phases, considerable shortcomings were discovered. The dire situation in the affected area, a variety of urgently required interventions, and the large number of aid organizations involved brought about difficulties in management, coordination, and communication among authorities and aid organizations. This article highlights flaws in management in the various aspects of this disaster in order to assess what was done, and what should be done to overcome these shortcomings in future disasters.

Methods: A retrospective review of the various aspects of management related to the Bam disaster was done via the assessment of files, multi-center studies, governmental data, and available literature from 2003–2008.

Results: A review of the available data relevant to search and rescue (S&R) operations and short-term aid provision revealed flaws in different aspects of disaster management including personnel, the transfer of the injured, availability medical supplies, treatment planning, problems concerning the composition of treatment forces dispatched to the region, distribution of tasks among treatment workers, transferring of equipment, availability of facilities, and lack of coordination among the organizations responsible for the management of the disaster. Most of the aforementioned issues have been addressed.

Conclusions: A comprehensive disaster management plan must not be limited only to the response phase, but rather must include: preparedness, recovery with optimal legislation and budgeting, improvement of healthcare facilities, and organized communication channels between the different governmental departments. This important issue has been addressed, and a disaster management organization under the supervision of the President has been established, developing a national S&R strategy and protocol for unified managerial organization, an alert system, an international disaster command system (under which S&R and emergency medical service teams can be deployed, increasing the efficacy and coordination of the arrival of foreign teams and the construction field hospitals), and developing a flowchart to coordinate international agencies and the domestic authorities in charge. Continuous education, training of the general population, conducting periodic exercise drills, and provision for prepared task force mobilization in disaster management all are important aspects of the management of disasters due to natural hazards.

Motamedi HMK, Saghafinia M, Bafarani AH, Panahi F: A reassessment and review of the Bam earthquake five years onward: What was done wrong? ***Prehosp Disaster Med*** **2009;24(5):453–460.**

Introduction

The country of Iran ranks 10th for the incidence of disasters due to natural hazards worldwide and earthquakes are a relatively common occurrence. On 26 December 2003, the residents of the ancient city of Bam, (a city 610 km southeast of Tehran that dates back 2,500 years), experienced an earthquake that measured 6.3–6.6 on the Richter scale and lasted 13 seconds. It destroyed more than 90% of the historic citadel Arg-e Bam, among other historic land-

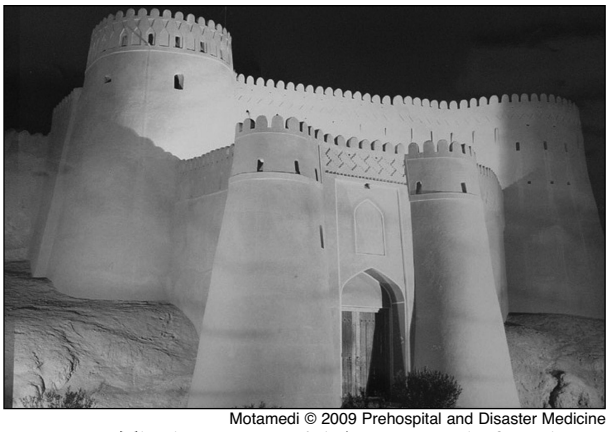

Figure 1—The historic citadel Arg-e Bam before the earthquake

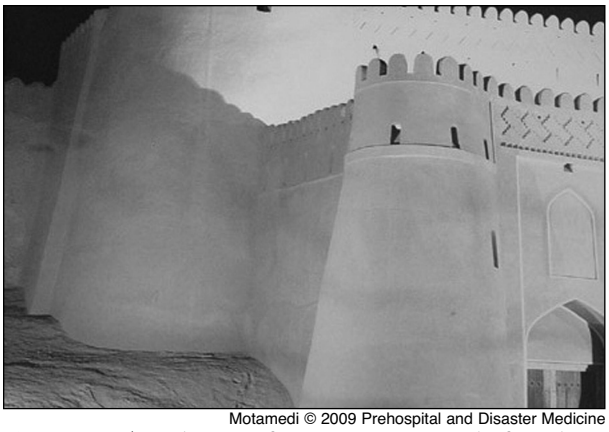

Figure 2—Aerial view of a mosque in Bam before the earthquake

Figure 3—Aerial view of the devastated city of Bam after the earthquake

Figure 4—Destroyed house in Bam

marks (Figures 1 and 2), as well as 80% of the city (Figures 3 and 4). The residents of the city experienced two minor earthquakes (tremors) at 22:00 hours (h) the night before and at 02:00 h in the morning prior to the major earthquake. Unfortunately, few heeded this warning. This quake ranked 7th in magnitude among earthquakes of the past century. Nearly all health service facilities and 120 schools were destroyed.[1–6] The water supply network was damaged and electricity and telephone lines were down.[7]A state of emergency was declared. In addition to recruiting medical and health teams, international search and rescue (S&R) teams and aid were dispatched to the area to provide medical care, air evacuation, and relief.[8] International relief teams also played an important role in the management of this disaster, as did humanitarian aid from throughout the country and abroad. At this stage (five years onward), it seemed prudent to reassess what was done then, and what has been done to better prepare for, and manage future catastrophes.

Methods

A retrospective review (2003–2008) of the various aspects of disaster management related to the Bam disaster was done via data collection from files, available literature, multi-center studies and governmental data relating to the quake. The issues assessed included: (1) the early warning phase; (2) search and rescue operations; (3) injury management; (4) task force mobilization; (5) transfer of victims, equipment and facilities; (6) coordination among relief organizations; (7) time taken for the rescuers to reach the scene and remove the casualties from the rubble; (8) triage of casualties; (9) assessment of the time under rubble; (10) complications (i.e., disseminated intravascular coagulation, adult respiratory distress syndrome, renal failure, etc.); (11) medical responses rendered; (12) efficacy of foreign field hospitals; (13) medical assistance of national military forces; (14) psychological distress among survivors; (14) mental health (post-traumatic stress disorder (PTSD), grief); (15) water supply, power, telephone, healthcare services; (15) construction and repair of toilets and showers; and (16) opium abuse in the victims.

Results

Early Warning

When reviewing the pattern and model of the minor earthquakes (tremors) before the major quake, there had been lack of early warning, thus increasing the death toll.

Search-and-Rescue Operations

A review of S&R operations and the provision of appropriate treatment within a short period of time revealed flaws

in some aspects of treatment management, including a lack of trained personnel, issues with the transfer of the injured, distribution of medical supplies, issues with treatment planning, problems concerning the composition of task forces dispatched to the region, problems with the distribution of tasks among healthcare workers, issues transferring of equipment, problems with the availability of facilities, and a lack of coordination among the organizations responsible for disaster management.[1] A cross-sectional study of 185 casualties who were transferred to and admitted to the University Hospital during the first week following the earthquake showed that the mean value of the duration of time taken for the first rescuers to reach the scene and remove the casualties from beneath the rubble was 1.7 ±2.7 and 0.9 ±1.1 hours, respectively.[2]

In 708 patients transferred to Chamran Hospital in Shiraz, Iran within the first two days after the earthquake, a retrospective study showed that extremity fractures (136, 19%) were more common than were axial skeleton fractures (28, 4%). Out of the total 708 patients, 152 (21.5%) patients needed emergency operations, 26 (4%) needed less urgent surgery, and 530 (74.5%) required wound care or antibiotic therapy and other forms of supportive care. Two patients had compartment syndromes of the leg, three required below-knee amputations, eight suffered acute renal failure, two developed fat emboli syndrome, and one had a brain injury that resulted in death.[3]

In a tertiary referral trauma management center in Tehran, 210 victims were assessed and the mean value for the time under rubble was 1.9 hours. The mean time between rescue and final medical treatment was 13.5 hours. There were 19 cases (9%) of compartment syndrome and 14 (6.7%) patients had impaired renal function. The incidence of compartment syndrome had a direct relation to the time under rubble, and the incidence of renal failure was directly related to the rescue-to-first medical aid time. Axial skeleton fractures, among them the lateral compression type pelvic fractures, were particularly common. Fractures associated with neural injuries also were common.[4]

A database study of 2,086 victims that were hospitalized within the first 10 days following the earthquake found that a longer time under the rubble was associated with acute renal failure (6.2 ±4.1 vs. 2.1 ±3.9 hours; p <0.001) and late hospitalization (3.1 ±2.8 vs. 1.5 ±1.7 days after the earthquake; p <0.001) as well as longer (16.7 ±12.8 vs. 12.5 ±11.3 days; p <0.001). Sepsis (11.6% vs. 0.5%), disseminated intravascular coagulation (7.3% vs. 0.3%), adult respiratory distress syndrome (9.1% vs. 1.4%), fasciotomy (38.9% vs. 1.9%), amputation (6.1% vs. 0.5%), and death (12.7% vs. 1.9%) were markedly more frequent among patients who developed acute renal failure (p <0.001).[5]

Satisfaction Scores

When assessing the satisfaction scores in 211 victims in 2005, transportation by aircraft to the backup hospitals received the highest score (4.2) on a scale of 1–10, (1 = very poor; 10 = very good), followed by international assistance (4.1), first medical care (3.5), search and rescue (3.3), and primary transportation (3.1). Reconstruction and the quality of access to the infrastructure of the city received a score of 2.6.[6]

Psychological Distress

Psychological distress measured using the 12-item General Health Questionnaire (GHQ-12) in 916 survivors showed that 58% of the respondents suffered from severe mental health problems as measured by the GHQ-12; three times higher than the prevalence of psychological distress among the general population. The results of the logistic regression analysis indicated that female gender, lower education, unemployment, and loss of family members were causes associated with severe psychological distress among earthquake victims.[9]

Post-Traumatic Stress Disorder

About 58% of 961 participants assessed in 2004 and 81% of the 145 participants in 2003 had developed PTSD according to *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV or DSM IV-TR) criteria.[9,10] A cross-sectional study of 400 persons selected by stratified, multi-stage area sampling of survivors interviewed in their temporary residential camp showed complicated grief was detected in 304 (76%) of the respondents.[11]

Drugs Prescribed

Relative to drugs prescribed, data collected randomly from 3,000 prescriptions for Bam outpatients who were examined by general practitioners from Emergency Medical Assistance Teams in 12 healthcare centers during the first six months after the Bam earthquake showed that the mean number of drugs/prescriptions was 3.5 per outpatient. Respiratory drugs were the most frequently used drugs (14.2%), followed by analgesics/non-steroidal anti-inflammatory drugs (11.3%), antibacterials (11.2%), gastrointestinal drugs (9.6%), and central nervous system drugs (7%). Penicillins (6.8%), cold preparations (8%), and systemic anti-acids (ranitidine and omeprazole) were among the 25 most frequently used drugs by outpatients and inhabitants of Bam during the first six months after the Bam earthquake. Oral administration was the most frequent method of administration (81.7%), followed by injections (10.9%).[12]

Opium Dependence

During the first two weeks after the earthquake, in drug-dependent interviewees (163), about half suffered from withdrawal symptoms. About half reported their problems to healthcare providers and asked for morphine or other analgesics. One-third had used opium on the first day and two-thirds during the second day to the end of the second week after the earthquake. Although smoking had been the most common means of abuse before the earthquake, oral intake had become the most prevalent route after the earthquake.[13]

Shelter

Earthquake-resistant shelters were lacking, and there were inadequate supplies of necessities to provide for the entire affected population.[14,15] Tents were set up, followed by mobile homes to accommodate the families of survivors. A number of international relief agencies assisted in providing humanitarian aid and emergency sanitation services.[16] European and Asian states, coordinated by the Red Cross and the Iranian Red Crescent organization were involved in this response.

Figure 5—An earthquake victim being rescued by natives of Bam immediately after the earthquake

Figure 7—Foreign rescue team and trained personnel and trained dogs to find victims still remaining under rubble

Discussion

Following the earthquake, 43,000 people were estimated to have been killed and 30,000 injured.[1–4] However, four months later, the Statistical Center of Iran reported 26,271 to have been killed (based on the identification documents annulled). Approximately 18,000 buildings were destroyed, and some 75,000 people were left homeless.[1] Issues requiring further debate include: (1) tremors or minor earthquakes before major one; (2) after insult and initiation of S&R; (3) triage, transfer; (4) major medical problems; and (5) primary healthcare.

Tremors Before the Major Earthquake

Sometimes there are warnings, such as series of minor quakes with increasing severity, that imply that more energy is going to be released soon. Had this been heeded in the case of the Bam earthquake, perhaps the number of casualties may have been reduced, as in the Lorestan earthquake in Iran that occurred on 30 March 2006, where different parts of western Lorestan Province had been rattled by small shocks prior to the major quake. This prompted early

Figure 6—Arrival of rescue personnel at a military base airport in Bam

warning and evacuation of most of the residents, decreasing the toll of victims considerably.

Initiation of Search-and-Rescue

Time Under Rubble and Time Taken for Rescuers to Reach the Scene and Evacuate—The majority (60.2%) of rescuers were natives of Bam who rescued the majority of the victims, a phenomenon which may be dangerous (Figure 5); upon the arrival of the national (Figure 6) and international (Figure 7) rescue teams and thereafter, rescues were done by trained personnel.[1–3,8] The city of Bam was divided into 13 zones. Rescue teams were dispatched to each zone simultaneously. In spite of the fact that the time taken to rescue victims (1.9 hours on average), the average time taken to get victims to final medical treatment was 13.5 hours.[4] Initial treatment at the first post comprised of cardiopulmonary resuscitation, intravenous fluid therapy, airway management, control of hemorrhage, and stabilization of the patient. Sodium bicarbonate was administered to victims who had sustained crush injuries.

One of the major shortcomings was an insufficient amount of equipment and search dogs, delaying proper digging and rescuing of victims under the rubble. Trained dogs now have been acquired for this purpose. Additionally, rescue teams have been established in all cities (by the Red Crescent Society, universities, and task forces) to overcome time-delays. Bulldozers were brought in on Day 2.[1] The discovery of an old woman under the rubble after seven days indicates that the search should not be terminated prematurely. The Red Crescent Society has trained more volunteers for S&R. This may prove beneficial to expedite S&R during future mass catastrophes.

Assessment of Rescue Operations—The status of the rescue, evacuation, and transportation of the casualties during the early stages following the earthquake, and information regarding different places of settlement after being rescued from the rubble and receiving initial medical care indicated that the emergency medical service (EMS) system in Bam was destroyed and unable to respond adequately. The national and international responses were not quickly

enacted because the situation was under-estimated.[1–3] Also, because the mass media, communication channels including telephone, cell phone, fax, and e-mail in Bam were destroyed, the survivors were unable to summon aid. Roads into and out of Bam were jammed, including air traffic. The airport was small, and there were numerous flights. Thus, the planes had to circle the airport until obtaining permission to land. The railways were also damaged.

To overcome this problem in future disasters, multiple methods of communication, including satellite phones and terminals, have been put in place in Bam, as well as in other cities. The airport, railway, and roads of Bam have been rebuilt and reconstructed to accommodate increased capacity.

Triage, Transfer, and Treatment

Triage of Casualties—At the Bam airport, triage was done during the evening following the tragedy because the field hospitals were not established until the next day, and the two major hospitals in Bam were destroyed. Triage was done primarily in the lobby of the airport, which was full of victims. The initial aim was to detect immediate priorities. Once the area was cleared, triage utilized the START (Simple Triage and Rapid Treatment) method categorized the victims into four classes (immediate, delayed, out-patient, deceased). Markers were used to write the category on the forehead of the patients because tags were unavailable. Four colors were used: red denoted immediate evacuation, yellow denoted delayed evacuation, green denoted ambulatory patients, and black denoted deceased or moribund patients.

The triage was effective and expedient. Nearly all of the casualties were evacuated from Bam within 48 hours; this expedient evacuation received an award (the Henry P. Davidson Award) from the International Federation of Red Cross and Red Crescent Societies. The Red Crescent Society is responsible for transportation of the victims to the collection point and EMS is responsible for transportation to the advanced medical posts.

It seems that it may be better to triage and evacuate the victims on-site by rescue teams. Field triage was performed on-site after rescue and again at the causalty collection point. In the more recent Lorestan earthquake, this was done more effectively using helicopters. One of the shortcomings of the Bam triage was the disorganized triage by various doctors (university doctors, native doctors, military doctors, the Red Crescent Society, etc.) without coordinated supervision. Triage now is done under the supervision of one physician, a delegate of the medical university of the province, who is the commander-in-charge of triage in each locale.[1–3]

Initial Trauma Management, Treatment Teams, and Coordination among Organizations—The collapse of health facilities in Bam was enormous. On the day of the earthquake, only first aid and limited necessities for basic prehospital and advanced trauma life-support were provided. After establishing field hospitals (48 hours after the earthquake), more advanced immediate medical and surgical care was rendered.[1–4] Despite the arrival of a significant number of healthcare providers, such as volunteers, nongovernmental organizations, military, governmental, and international aid workers, they were unable to act efficiently because of problems with not having proper personnel. The Red Crescent, international relief teams, and military forces also have experienced this in similar events in other countries. The first field hospitals were deployed by the National Guards, and later by Red Crescent, international relief team, and military forces. They provided the first medical facilities for 39.8% of the casualties.[7]

Disorganized aid was prevalent, causing lack of coordination and delivery of unspecialized aid. Specialized aid forces have been established and earthquake protocols have been formulated by the Ministry of Health to be implemented in future disasters.

Medical Assistance Conducted by the Military—The military were the first to spread the news and initiate S&R missions (within hours after the earthquake). They set up the first three field hospitals in the disaster area, transported 937 victims, and brought in medical and healthcare personnel to the disaster area on Day 1. They also set up 23 field-emergency and 13 field-assistance centers in the area, provided eight post-hospital care centers throughout the country, and played a significant role in airlifting 11,792 casualties to different hospitals throughout the country.[1]

Arrival and Implementation of Foreign Field Hospitals—At first, the true extent of the disaster was under-estimated, but soon became apparent. During the first six days following the quake, foreign aid arrived and helped in the relief phase, also establishing a number of field hospitals (Figures 8, 9, and 10). Approximately 60 countries provided foreign aid.[7] Arrival was late because of late notification (approximately 13 hours after the earthquake). Their teams had between 7 and 80 personnel, between 4 and 22 doctors, between five and 200 beds, and performed between two and 483 operations during their stays.[7] Since all victims were evacuated within the first two days, there were no patients with major surgical needs upon the arrival of foreign aid. Thus, in order to be effective, these teams must be notified early and arrive early after an earthquake.

Major Medical Problems

Disseminated Intravascular Coagulation, Adult Respiratory Distress Syndrome, and Acute Renal Failure—Despite the fact that the initial findings of the victims of the Bam earthquake were not well-documented, sepsis, disseminated intravascular coagulation, acute respiratory distress syndrome, need for fasciotomy, and amputation were the most frequent delayed findings reported among the victims transported to Tehran and other cities among patients who had developed impaired renal function. Thus, institution of protective protocols from the very first hours after injury and more conservative approaches to treatment of fractures in crush injury patients, intravenous fluid therapy, and administration of sodium bicarbonate have been recommended.[4] Nonetheless, early extrication and quick hospitalization with appropriate multidisciplinary care are cornerstones of management to prevent acute renal failure and its subsequent mortality in earthquake victims.[5]

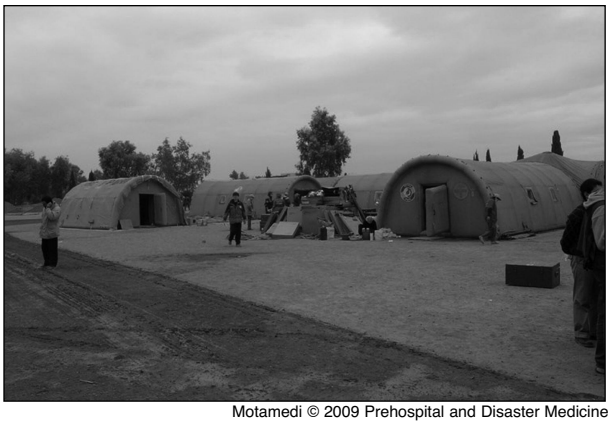

Figure 8—Foreign field hospital setup in Bam

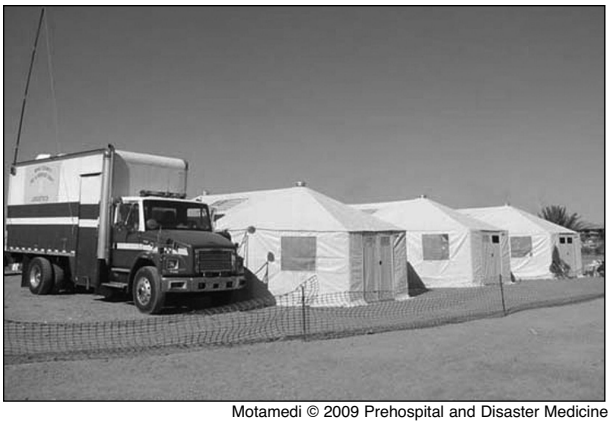

Figure 9—American field hospital tents setup in Bam

Figure 10—Clean water supply facility of the American field hospital

Psychological Distress and Post-Traumatic Stress Disorder among Victims—Findings indicated that the amount of psychological distress among earthquake survivors was high and that there was an urgent need to deliver mental health care to disaster victims in local medical settings in order to reduce the negative health impacts of the earthquake. Psychological counseling was needed for those who survived the event.[9] Psychological distress among Bam earthquake survivors, and factors associated with severe mental health problems, were common among those who survived the earthquake. About 58–81% of the respondents suffered from severe mental health problems (three times higher than the prevalence of psychological distress among the general population).[9,10] The finding of complicated grief in more than two-thirds of respondents required more attention of mental health services. Rebuilding of homes, finding a place for survivors to live, and respecting cultural and ethnic customs of the survivors are all factors in helping survivors to regain their mental health within a shorter period of time.[11]

Commonly Used Drugs—Respiratory drugs were reported to be the most frequently used drugs (14.2%), followed by analgesics/non-steroidal anti-inflammatory drugs (11.3%), and antibacterials (11.2%).[12] There were problems with drug distribution during the first 24-48 hours. Fluids were administered to prevent crush syndrome and impending acute tubular necrosis or Acute Renal Failure. Availability of normal saline was limited during the first 24–48 hours and was needed to increase diuresis and prevent kidney damage. The Iranian Ministry of Health has issued a protocol, as well as drug-distribution posts, for this purpose in cities throughout the country.

Primary Health Care

Shelter—Tents were provided to survivors and were set up in front of their homes to prevent theft.[6] Earthquake resistant mobile homes were provided to the homeless natives of Bam prior to establishing permanent shelters. Later, laws were implemented for requiring reconstructed buildings to be earthquake-resistant,[14] including hospitals. Hospitals in other provinces, including Tehran, have been reinforced as well.

Food and Nutrition—Food, bottled water, and other essentials were provided and distributed throughout the city. Unfortunately, because of improper data collection and problems with distribution, the supplies of these necessities were inadequate to cover the entire affected population.[15] Another problem was non-victims coming in from unaffected suburbs of Bam to obtain free food.

Reproductive Health—In the aftermath of the event, there was inadequate provision of specific reproductive health and hygienic supplies, services, and distribution of these items.

Environmental Health, Water Supply, Power, Telephone, Healthcare Services, Constructing and Repair of Toilets and Showers

The city's water supply was destroyed. Water tankers and bottled water were brought into the city. This contributed greatly to the prevention of the development of communicable infections, diseases, and epidemics in Bam. The power supply was destroyed, as were the telephone lines. These were restored within two to three days. A number of international relief agencies assisted in providing emergency sanitation services by constructing and repairing toilets and showers in villages located outside of the city.[16]

Other Important Issues

Weather Conditions—On the night of the earthquake, the temperature dropped below 0°C. This caused problems due

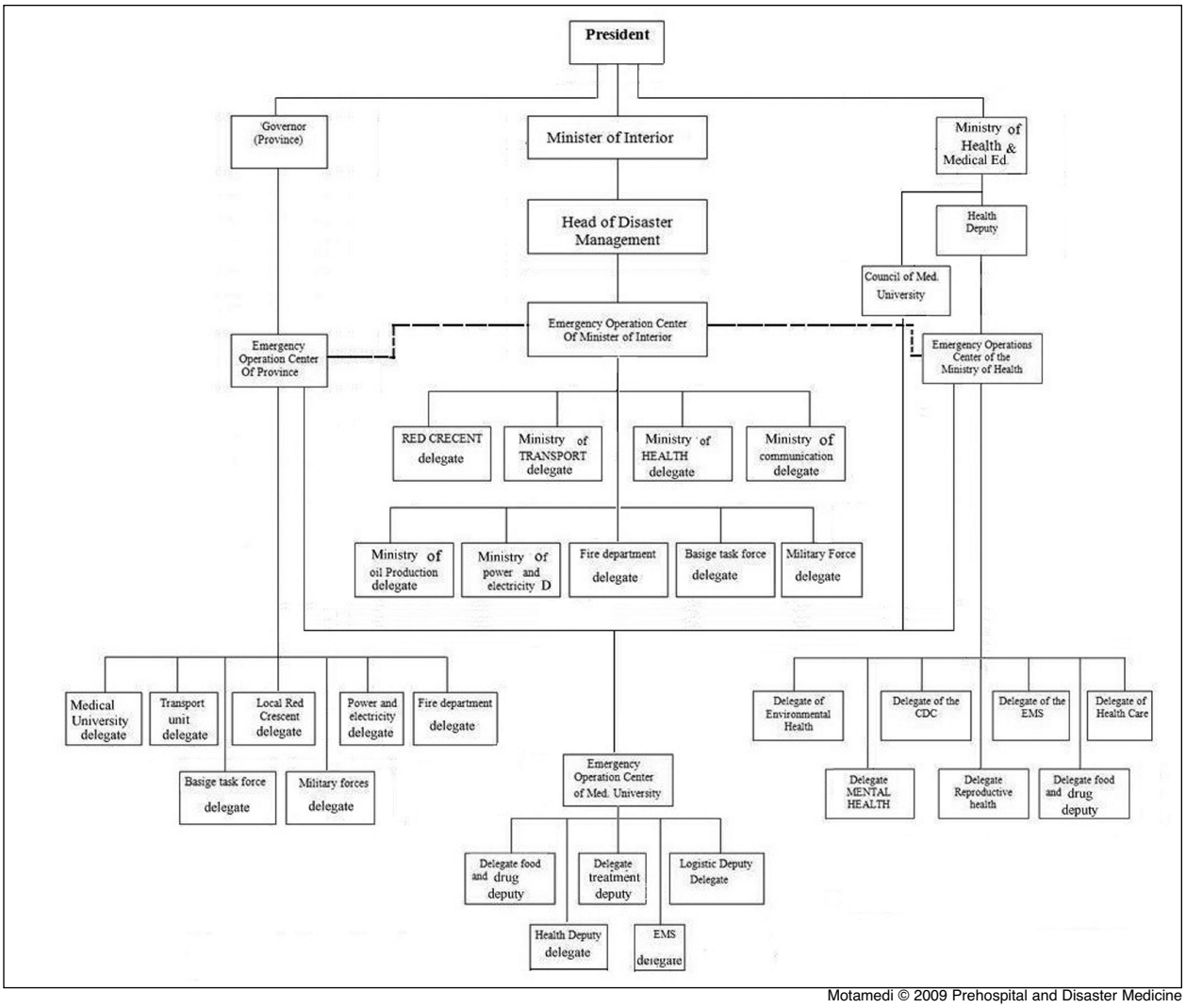

Figure 11—Organizational chart for disaste management. Note emergency operation centers are coordinated with each other

to a lack of heating, leading to an increase in respiratory infections during the following days.[1] However, the cold temperature also was beneficial as it prevented the decay of the corpses not yet buried.

Opium Abuse in the Victims—Opium abuse, which had been relatively prevalent among the male population in Bam, caused problems after the earthquake. During the first two weeks after the earthquake, about half of drug-dependent interviewees (163 earthquake survivors) suffered from withdrawal symptoms. About half of these reported their problems to healthcare providers and asked for morphine or other analgesics. One-third had used opium on the first day and two-thirds had used opium by the end of the second week after the earthquake.[13] Almost all of them obtained their opium from inhabitants of other cities as gifts. Members of rescue and health delivery systems had a numerous encounters with opium addicts, especially during the first three days after the earthquake, and prescribed morphine and other analgesics. In societies with a considerable prevalence of substance abuse, this issue becomes an important problem for both society and the healthcare system during times of disaster, and the necessary arrangements to deal with it should be present beforehand.[13]

Community Preparedness—Raising awareness and training of the community renders the community and volunteers more capable to cope with future disasters.[17] The present organization of governmental bodies in charge of EMS and disaster management is illustrated in Figure 11.

Conclusions

A comprehensive disaster management plan must not be limited only to the relief phase, but rather must include preparedness, recovery with optimal legislation and budgeting, improvement of healthcare facilities, and provision of organized communication channels between the different governmental departments. These are basic tools for operating a proper command system and instituting inter-agency coordination among relief workers. An organization under the direct supervision of the government should be established for this purpose. This important issue has been

addressed and the Disaster Management Organization has been established under the direct supervision of the President. Continuous education, training for general population and the people involved in disaster management, and exercise drills based on potential hazards and composed of primary training using scenarios and tabletop exercises all are important aspects of preparedness for disasters due to natural hazards.

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