

Original Article

Practical Strategies to Reduce Morbidity and Mortality of Natural Catastrophes: A Retrospective Study Based on Bam Earthquake Experience

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Background: Critical analysis of shortcomings of emergency medical management of earthquake casualties will provide an invaluable insight to improve outcomes for future events. Using a critical analysis methodology to evaluate the quality of emergency medical management after Bam earthquake, we suggest a practical strategic approach to decrease morbidity and mortality after such events.

Methods: We designed a questioner to register the basic demographic data and the key biologic parameters of all rescued victims arriving in hospitals. Based on that questioner a data bank was created and used for different analyses. In addition, published official reports and on the scene observations of our nephrologist colleagues were other sources of our data.

Results: Bam earthquake was publicly announced more than six hours after its occurrence. The earliest time when local and international rescue teams arrived at the scene was 12 hours after the disaster. Fifty-four percent of hospital inpatients had been admitted on the second or third day after the earthquake. The mean time of being under the rubble was 4.8 ± 4.9 hours. The mean time between extrication and initiation of intravenous fluid infusion was 18.9 hours (min: 10 minutes, max: 96 hours).

Conclusion: Problems encountered in the aftermath of the Bam earthquake were related to the lack of prepared action plan and data management system. Here, we present a specifically designed earthquake chart. By following the chart, rescue paramedic personnel and emergency medical teams will be able to recognize high-risk victims, in order to provide timely medical management.

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Introduction

On December 26, 2003 at 5:26 AM local time, the city of Bam and its historic citadel were devastated by an earthquake. The United States Geological Survey estimated its magnitude as 6.6 on the Richter scale. The British Broadcast Corporation (BBC) reported "70% of the modern city of Bam" was destroyed. Death toll numbers as high as 80,000 were rumored on the street and 70,000 reported in the media. However, the total death toll was reported as 56,230 on January 17 and the latest estimate from statistical center of Iran has halved previous

estimates to 26,271 deaths. An additional 10,000 – 50,000 were reported injured; however, this number is very uncertain. The most reported number of injured people is 30,000, which may have been originated from an early Reuters account. Before Marmara earthquake,¹ only a few restricted observational studies on medical problems after earthquake had been published.² Information obtained from these studies can be used for future rescue plans by civil and medical teams. Usually, after earthquakes, because of destruction of local infrastructures and medical facilities, patient overload, chaotic situation, heavy work load, and poor knowledge of paramedics, human casualties are escalating. In this study, using experiences from Bam and pervious similar settings in Manjil-Rudbar earthquake (Iran, 1990),³⁻⁵ we suggest strategies to improve emergency postearthquake medical services.

Materials and Methods

Based on official reports of local authorities, personal observations in the aftermath scene, and data provided by our survey questionnaire, a retrospective data bank was created. Time under rubble, extrication to needle time defined as the duration between extrication of victim to starting intravenous fluid infusion, mean volume of intravenous fluid infused in the first 24 hours, mean urine output in the first five days after

hospital admission, serum blood urea nitrogen (BUN), serum creatinine, and serum creatine phosphokinase (CPK) levels were the selected data for analysis.

Statistical analysis

Descriptive analyses including minimum and maximum values were performed and the mean±SD values were calculated.

Results

Disaster was publicly announced more than six hours after its occurrence. Local and international rescue teams reached the scene at the earliest 12 hours after the disaster. Approximately 142,000 people, inhabitants of the town and its surroundings, were affected. There were 25,514 dead, 30,000 injured and nearly 12,000 patients referred to hospitals.

Out of the 12,000 patients referred to medical care centers, 5000 were treated in outpatient department, and 7000 were admitted to the hospitals. In hospital inpatients, we detected 4552 charts (46% women) at 15 hospitals of seven cities. Of them only 65% (2984/4552) had acceptable medical records. The response rate to some of our questions is shown in Figure 1. Admission date, sex, death, fasciotomy and dialysis needed, sepsis, disseminated intravascular coagulation, acute respiratory distress syndrome (ARDS) were among

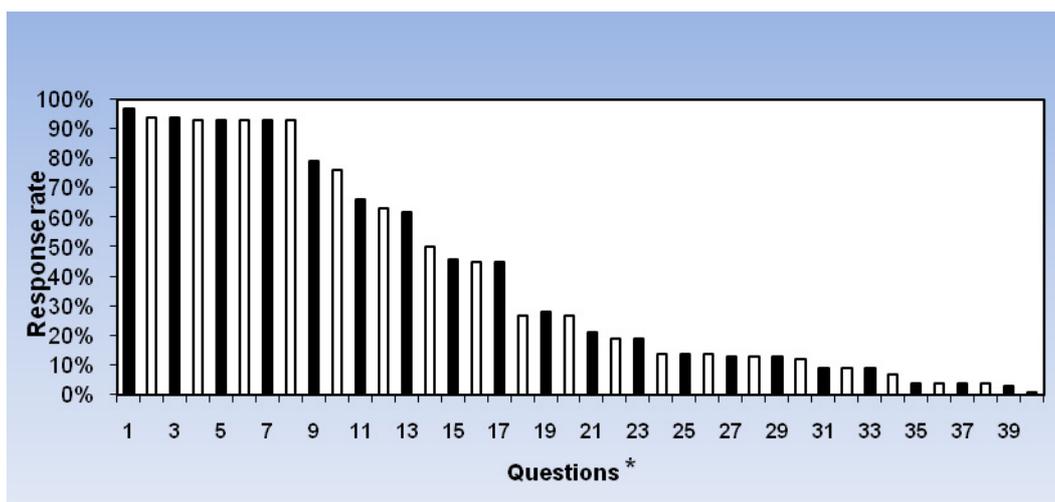


Figure 1. The response rate to some of the questions.

*1=admission date, 2=sex, 3=death, 4=fasciotomy needed, 5=dialysis needed, 6=sepsis, 7=DIC, 8=ARDS, 9=amputation, 10=systolic BP, 11=discharge date, 12=diastolic BP, 13=age, 14=pulse rate, 15=IV fluid intake day1, 16=IV fluid type day1, 17=bicarbonate day1, 18=IV fluid intake day2, 19=IV fluid type day2, 20=bicarbonate day2, 21=IV fluid intake day3, 22=IV fluid type day3, 23=bicarbonate day3, 24=bicarbonate day4, 25=IV fluid intake day4, 26=IV fluid type day4, 27=first 24h IV fluid, 28=first 24h oral intake, 29=IV fluid intake day5, 30=output day1, 31=output day2, 32=output day3, 33=output day4, 34=IV fluid type day 5, 35=bicarbonate day 5, 36=dialysis session, 37=output day5, 38=dialysis hours, 39=death cause, 40=dark urine, 40=Hemodialysis session. IV=intravenous, BP=blood pressure, DIC=disseminated intravascular coagulation, ARDS=acute respiratory distress syndrome.

the most complete variables with more than 90% response rate while fluid intake, urine output, type of intravascular fluid, dialysis sessions and duration, cause of death, and dark urine were parameters with less than 20% response rate. The response rate of other parameters was between (20 – 90%).

In patients whose admission dates were recorded, 19.9% (558/2793) were admitted on day 1, 45% (1277/2793) on day 2, 8.5% (237/2793) on day 3, and 5.5% (155/2793) on the fourth day after the quake.

The mean time under rubble was 4.8 ± 4.9 hours, 16% being trapped for one hour. The average extrication to needle time and beginning of intravenous infusion was 18.9 hours.

A considerable number (23%) of victims received their first intravenous infusion within 12 hours after the quake (earliest: 10 minutes, latest: 96 hours).

The mean volume of intravenous fluid infused in the first 24 hours was 1800 mL (min: 0, max: 6000 mL) and the mean volume of daily intravenous fluid administered five days after the quake was 2,800 mL (min: 200 mL, max: 10,000 mL).

The mean urine output was 2200 ± 1900 mL (min: 170, max: 8700). For the patients whose first 24-hour urine output was reported (only 199 patients), oliguria (defined as less than 200 mL of urine output in a 24-hour period) was recorded in only 43 patients (21.6%). These patients were the only whose urine discoloration status was reported. Of whom 39 patients had dark urine.

First biochemical parameters were checked for only 57% (1339/2310) of the patients at day 1. Table 1 shows the percentage for parameters checked at the first 24 hours. BUN and creatinine were checked in 35% (822/2310), potassium in 33% (765/2310), and CPK in 14% (333/2310). In patients with documented death status, 1.7% (48/2701) died in hospitals.

Discussion

After Bam earthquake a major panic was experienced. Patients overload, chaotic situation, and heavy work load led to imperfect management and incomplete healthcare records. Despite these conditions, out of the 12,000 patients admitted to medical care centers, we could finally detect 4,552 patients who were admitted to 15 medical centers

Table 1. Percentage of some parameters checked at the first 24 hours after Bam earthquake.

Parameter	%	Parameter	%
CPK	14	Phosphorus	5
LDH	10	Calcium	6
SGOT	5	WBC	47
BUN	35	Hemoglobin	47
Creatinine	35	Potassium	33

CPK=creatinine phosphokinase; LDH=lactate dehydrogenase; SGOT=serum glutamic oxaloacetic transaminase; BUN=blood urea nitrogen.

in seven cities (Kerman, Tehran, Isfahan, Zahedan, Bandarabbas, Bushehr, and Shiraz).

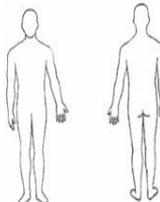
The huge lag between referred patients and patients admitted to hospitals was resulted from: 1) management of a large number of patients at the outpatient settings, which led to 7000 patients without any appropriate documentation and formal chart, and 2) inability to assess patients' records in some centers because of poor cooperation of the authorities.

Unfortunately, even in hospital inpatients, lots of data were missed and there were only 2984 (65%) patients with acceptable data on at least one of the parameters such as admission date, time under rubble, extrication to needle time, mean volume of intravenous fluid infused in the first 24 hours, mean urine output, BUN, creatinine, CPK, and potassium.

Because of six hours late announcement, local and international rescue teams reached the scene after approximately 12 hours, and victims were trapped under the rubble in an average for five hours. Unfortunately, the efforts of rescue teams had only a minor impact on survival of the victims. By the time they arrived, severely injured patients had already been transferred to local or distant hospitals by personal cars and public transportation. The time under rubble is an important factor for both medical and logistical concerns.⁶⁻⁸ Survival rates increase exponentially with the speed of extrication and hospital management of victims.

One of the other obvious pitfalls is delayed hospital admission. In our previous report regarding Bam earthquake and nephrologic perspective,⁹ we stressed the role of early hospital admission in decreasing renal problems, need for dialysis, and other complications. About 54% of those who were in need for hospital admission were admitted on the second and third day after earthquake. Regarding prophylactic hydration

Form 1. Special chart for patients' records and guidance of paramedics to stepwise approach to casualties.

A) Admission				Earthquake Chart			
Center:		Name & position of register:		Date:			
Patient name family:		Age/Sex:		Admission date:			
Patient Tel:		Weight:		Referred from:			
General appearance:		State of consciousness:		Kidney / peripheral nerve state:			
Pulse		Awake		Oligoanuria			
Blood pressure		Lethargy		Urine discoloration			
Respiratory rate		Coma		Foot drop			
Temperature				Wrist drop			
Mark trauma site with specific code							
Code	Trauma						
1	Superficial aberration						
2	Echymosis						
3	Induration / Edema						
4	Necrosis / laceration						
5	Deep wound						
6	Close fracture						
7	Open fracture						
Mark abnormalities in box				Mark abnormalities pulses			
Limb	Sensation	motion	Sever pain	<u>Right</u>			<u>Left</u>
Right upper				Brachial			Brachial
Left upper				Radial			Radial
Right lower				Femoral			Femoral
Left lower				Popliteal			Popliteal
				DP			DP
Past medical history: Diabetes: Hypertension: Nephrologic problem: Allergy:							
Check following as soon as possible: Hb , HCT , WBC , BUN , Cr , CPK , U/A , K , Urine Test tape:							
B) Discharge:		Date:		Referred to:		Refer cause:	
Surgery:		Type:		Date:			
Fasciotomy:		Limb:		Date:		Incision Number / Indication:	
Dialysis:		Start date:		End date:		Cession Number / Duration / Date:	
Complication: Sepsis:		DIC:		ARDS:		Amputation:	
Death:		Date:		Cause:			

Form 2 (A). For every patient, during hospital admission, these parameters should be checked and recorded every day.

Alb	PTT	PT	Ca	P	UA	SGOT	LDH	CPK	K	Na	Cr	BUN	BS	PLT	Hb	WBC	Date?

Alb=serum albumin; Ca=calcium; P=phosphorus; UA=uric acid; K=potassium; Na=sodium; Cr=creatinine; BS= blood sugar; PLT=platelet; Hb=hemoglobin; WBC=white blood cell.

Form 2 (B). For every patient, during hospital admission, vital sign, intake/output, and report of urine analysis should be recorded every day.

Urinary casts	Blood	WBC	Ketone	Pro	Blood	SG	pH	Out put	Lasix	Mannitol	Bicarbonate	Type of intravenous fluid	Intravenous fluid volume	Temp	PR	BP	Date

RBC=red blood cell; WBC=white blood cell; Pro=protein; Temp=temperature; PR=pulse rate; BP=blood pressure; SG=specific gravity.

therapy, we should declare that volume and initiation time of intravenous fluid therapy (mean: 1800 mL and 18 hours) were not appropriate based on previous accepted approach to such patients.^{10,11} It is true that the direct impact of trauma is the primary reason for all casualties, but the second most frequent cause is reported to be crush syndrome and its related complications such as compartment syndrome and acute renal failure.^{12,13} Therefore, laboratory parameters including hemoglobin, BUN, creatinine, CPK, sodium, potassium, calcium, and phosphorus should be checked at the earliest time. In Bam earthquake, laboratory parameters were checked for only 57% (1339/2310) of the patients at day 1 (Table 1). BUN and creatinine were checked in 35% (822/2310), potassium in 33% (765/2310), and CPK in 14% (333/2310). Our survey showed that in hospitals of small cities surrounding the epicenter of Bam, among 430 hospital inpatients, serum BUN and creatinine had been checked for only one fourth on the first day after hospital admission (0% to 50% in different centers). And muscle enzymes were measured for only less than 1% of these patients. This denotes improper training and management in the handling of such problematic patients. Report of urine discoloration as one of the first and important presentations of rhabdomyolysis process, was done only in the most injured patients with oliguria (43 patients), while it should be considered in most of patients, as an early, easy, applicable, and free of cost task.

In patients with documented death status, 1.7% (48/2701) died in hospitals. This makes 240 (1.7%×12000) deaths among hospital inpatients throughout the country; thus, approximately 0.9% (240/25514) of the total deaths occurred in hospitals. Based on observational findings, in addition to delay in extrication and initiation of first aid, rapid suffocation by dust caused by demolished mud bricks was one of the other reasons for such a high mortality (25,514) in the scene of the catastrophe.

Acute renal failure is another common and important cause of mortality and morbidity in earthquake victims. Almost 0.5% of casualties in Manjil-Rudbar earthquake,³ 2 – 5% in Tangshan earthquake,² 7.5% in Kobe earthquake,¹⁴ 12% in Marmara earthquake,^{11,15,16} and 24.7% in Mexico City earthquake,¹⁷ had developed this complication. In contrast, in the earthquakes of Nicaragua, El Salvador, and Guatemala,

rhabdomyolysis and/or acute renal failure were rarely diagnosed.^{18,19} The number of patients with acute renal failure after Bam earthquake 200 (4.3%) is drastically different from what has been reported from Mexico and Marmara.⁹ We presume that many of the severely injured victims died on the scene, almost 99% of total mortality.

To summarize, delayed announcement, poorly organized and educated rescue teams, delay in extrication and first aids delivery, substandard transportation, overloading of local hospitals, and incomplete patients' records were some of the important pitfalls we encountered in the aftermath of the disaster.

One of our most essential strategies to improve management and medical records is designing an earthquake chart. This chart, as it is shown in Forms 1 and 2, is consisted of four consecutive sections of admission, discharge, laboratory data, and intake/output. The main purpose of designing the chart is not only obtaining an accurate patient record but providing guidance for paramedics to apply a stepwise approach for rescuing victims.

Based on our findings, the following suggestions are recommended to decrease morbidity and mortality after natural catastrophes:

- Timely activation of rescue teams.
- Training rescue teams according to an standardized curriculum.
- Establishing emergency medical care at the scene in the first hours after earthquake.
- Providing prompt air transfer services for the critically ill victims.
- Applying the quick assessment and management charts/forms at the scene by paramedics.
- Establishing a national on-line data bank to collect and analyze the data.

Other general suggestions are as follow:

Increase knowledge about earthquake-prone areas, building construction resistance to quake, fire, floods etc. Continuous training programs for students in schools and universities as well as general population. Permanent disaster relief team organizations with national and international activities.

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References

- 1 Sever MS, Ereğ E, Vanholder R, Akoglu E, Yavuz M, Ergin H, et al. Marmara Earthquake Study Group: the Marmara earthquake: epidemiological analysis of the victims with nephrological problems. *Kidney Int.* 2001; **60**: 1114 – 1123.
- 2 Sheng ZY. Medical support in the Tangshan earthquake: a review of the management of mass casualties and certain major injuries. *J Trauma.* 1987; **27**: 1130 – 1135.
- 3 Atef MR, Nadjatfi I, Boroumand B, Rastegar A. Acute renal failure in earthquake victims in Iran: epidemiology and management. *Q J Med.* 1994; **87**: 35 – 40.
- 4 Nadjafi I, Atef MR, Broumand B, Rastegar A. Suggested guidelines for treatment of acute renal failure in earthquake victims. *Ren Fail.* 1997; **19**: 655 – 664.
- 5 Solez K, Nadjafi I, Atef Zafarmand AR, Collins AJ. Early low technology intervention lessons from the 1990 earthquake in Iran. Planning of dialysis for disasters. In: Jacobs C, Kjellstrand CM, Koch KM, Winchester JF, eds. *Replacement of Renal Function by Dialysis*. 4th ed. The Netherlands: Springer Netherlands; 1996: 1441 – 1454.
- 6 Noji EK. Prophylaxis of acute renal failure in traumatic rhabdomyolysis. *N Engl J Med.* 1990; **323**: 550 – 551.
- 7 Noji EK, Armenian HK, Oganessian A. Issues of rescue and medical care following the 1988 Armenian earthquake. *Int J Epidemiol.* 1993; **22**: 1070 – 1076.
- 8 Schultz CH, Koenig KL, Noji EK. A medical disaster response to reduce immediate mortality after an earthquake. *N Engl J Med.* 1996; **334**: 438 – 444.
- 9 Hatamizadeh P, Najafi I, Vanholder R, Rashid-Farokhi F, Sanadgol H, Seyrafiyan S, et al. Epidemiologic aspects of the Bam earthquake in Iran: the nephrologic perspective. *Am J Kidney Dis.* 2006; **47**: 428 – 438.
- 10 Better OS. The crush syndrome revisited (1940 – 1990). *Nephron.* 1990; **55**: 97 – 103.
- 11 Tolouian R, Wild D, Lashkari MH, Najafi I. Oral alkalinizing solution as a potential prophylaxis against myoglobinuric acute renal failure: preliminary data from healthy volunteers. *Nephrol Dial Transplant.* 2005; **20**: 1228 – 1231.
- 12 Ukai T. The great Hanshin-Awaji earthquake and the problems with emergency medical care. *Ren Fail.* 1997; **19**: 633 – 645.
- 13 Vanholder R, Sever MS, Ereğ E, Lamier N. Acute renal failure related to crush syndrome: towards an era of seismo-nephrology? *Nephrol Dial Transplant.* 2000; **15**: 1517 – 1521.
- 14 Oda Y, Shindoh M, Yukioka H, Nishi S, Fujimori M, Asada A. Crush syndrome sustained in the 1995 Kobe, Japan, earthquake: treatment and outcome. *Ann Emerg Med.* 1997; **30**: 507 – 512.
- 15 Vanholder R, Sever MS, De Smet M, Ereğ E, Lameire N. Intervention of the Renal Disaster Relief Task Force in the 1999 Marmara, Turkey, earthquake. *Kidney Int.* 2001; **59**: 783 – 791.
- 16 Sever MS, Ereğ E, Vanholder R, Ozener C, Yavuz M, Ergin H, et al. Marmara Earthquake Study Group: the Marmara earthquake: admission laboratory features of patients with nephrological problems. *Nephrol Dial Transplant.* 2002; **17**: 1025 – 1031.
- 17 Villazon-Sahagun A. Mexico City earthquake: medical response. *J World Assoc Emerg Dis Med.* 1986; **2**: 15 – 20.
- 18 Whittaker R, Fareed D, Green P, Barry P, Borge A, Fletes-Barrios R. Earthquake disaster in Nicaragua: reflections on the initial management of massive casualties. *J Trauma.* 1974; **14**: 37 – 43.
- 19 De Ville de Goyet C, del Cid E, Romero A, Jeannee E, Lechat M. Earthquake in Guatemala: epidemiologic evaluation of the relief effort. *Bull Pan Am Health Organ.* 1976; **10**: 95 – 109.