Nephrol Dial Transplant (2002) 17: 33–40

Dialysis and Transplantation News

Nephrology Dialysis Transplantation

An overview of morbidity and mortality in patients with acute renal failure due to crush syndrome: the Marmara earthquake experience

Ekrem Erek[1], Mehmet Şükrü Sever[2], Kamil Serdengeçti[1], Raymond Vanholder[3], Emel Akoğlu[4], Mahmut Yavuz[5], Hülya Ergin[6], Mustafa Tekçe[7], Neval Duman[8], Norbert Lameire[3] and Turkish Study Group of Disaster

[1]Cerrahpaşa, Medical Faculty Istanbul, Turkey, [2]Istanbul Medical Faculty, Istanbul, Turkey, [3]Gent, Belgium, [4]Marmara University, Istanbul, Turkey, [5]Uludağ University, Bursa, Turkey, [6]Göztepe Social Security Hospital, Istanbul, Turkey, [7]Kartal State Hospital, Istanbul and [8]Ankara Medical Faculty, Ankara, Turkey

Abstract

Background. On August 17, 1999 a major earthquake hit the most densely populated area at the eastern end of the Marmara Sea in northwestern Turkey. The number of documented cases of acute renal failure (ARF) following this event exceeded all similar cases previously reported for any single earthquake. The aim of this report was to provide an overview of the morbidity and mortality of all documented patients with ARF, due to crush injury, that were treated in hospitals with dialysis units following the Marmara earthquake.

Methods. Special questionnaires were sent out to all hospitals with dialysis units known to have admitted earthquake victims with ARF and related crush injuries. Responses to questionnaires from the Turkish Society of Nephrology (TSN) Task Force were collected from 35 hospitals in October 1999. We retrospectively evaluated patients, clinic and laboratory findings, surgical interventions, and frequency and duration of dialysis. Patients who died before or on admission and those with prior chronic renal disease were excluded from the study.

Results. A total of 639 patients (291 female and 348 male) with ARF due to crush injury were hospitalized in 35 hospitals. The mean age was 31.6 ± 14.7 years and 71.1% were young adults within the range of 16–45 years. 477 patients (74.6%) received one or more dialysis treatments, 162 patients were not dialysed, 15 patients died before dialysis could be instituted, and 147 patients recovered without dialysis treatment. 340 patients were oliguric on admission. The most important abnormalities related to ARF as a result of crush injury morbidity, were oliguria (53.2%), uraemia (94%), high creatinine levels (87%), hyperkalaemia (42%), hyperphosphataemia (63%), hypocalcaemia (83%), and high creatinine phosphokinase levels (73 %). 512 patients had a total of 790 extremity injuries. Eighty-three patients (12.9%) had fractures of the extremities and non-extremity fractures were observed in 59 (9.2%) patients. 323 fasciotomies were performed. Thoracic and abdominal trauma was observed in 110 patients (17.2%). Infection and sepsis were observed in 223 (34.9%) and 121 (18.9%) patients, respectively. Haematologic abnormalities were observed in 197 patients (33%) including 116 with Htc $\leqslant 30\%$. There were pulmonary problems in 96 patients (15%), cardiovascular problems in 198 patients (30.9%), gastrointestinal problems in 23 (3.16%), neurologic problems in 43 (6.7%), and psychiatric problems in 7 (1%) patients. Ninety-seven of the 639 patients with ARF as a result of crush injury died (15.2%), and mortality rates were 17.2 and 9.3% in dialysed and non-dialysed patients, respectively. Findings significantly associated with mortality were sepsis, thrombocytopenia, disseminated intravascular coagulation (DIC), acute respiratory distress syndrome (ARDS), and abdominal and thoracic traumas.

Conclusions. We conclude that in cases of severe disasters such as major earthquakes, patients should be rapidly transferred to undamaged peripheral general hospitals. When proper dialysis and intensive care facilities together with around the clock dedicated human effort are available, crush injury-related ARF patients have a lower mortality. Mortality, when it occurs, is mainly associated with thoracic and abdominal trauma and medical problems such as DIC and/or ARDS/respiratory failure, often in conjunction with sepsis.

Correspondence and offprint requests to: Ekrem Erek, Cerrahpaşa Tıp Fakültesi, İç Hastalıkları Nefroloji Bilim Dalı, Cerrahpaşa, Aksaray, 34300 Istanbul, Turkey. Email: e.erek@mail.com

Keywords: acute renal failure; crush injuries; morbidity; mortality; Marmara earthquake

Introduction

At 03:02 (local time) on August 17, 1999 Turkey suffered from the effects of a devastating earthquake, registering 7.4 on the Richter Scale. The epicentre was located in Gölcük, a town near Izmit City in the Kocaeli province at the eastern end of Marmara Sea. The earthquake, subsequently known as 'Marmara', caused severe damage and the collapse of buildings over a 300 km distance and covered a total area of 64 365 km^2 in 10 provinces of the most densely populated and heavily industrialized regions of northwestern of Turkey (Bilecik, Bolu, Eskişehir, Istanbul, Kocaeli, Sakarya, Tekirdağ, Yalova, Zonguldak).

Of the 15.8 million inhabitants in the area, 80% were city-dwellers, and the casuality figures of 17 479 deaths and 43 953 injuries [1] with 24 000 hospitalizations [2], were not surprising since the quake occurred at a time when people were sleeping. Most of the deaths resulted from crush or suffocation in collapsed dwellings. The number of moderately damaged buildings was ~77 200 [3], and the number of heavily damaged or completely collapsed buildings was ~77 297 (Table 1).

The 'Marmara' was the second deadliest earthquake faced by Turkey in twentieth century, being surpassed by Erzincan quake, which took about 33 000 lives in 1939 [4]. Although Turkey is an earthquake prone country, this event was a new experience because the widespread earthquake area covered many densely populated and industrialized cities and towns.

The aim of this report was to provide an overview of the morbidity and mortality of all the documented patients with ARF as a result of crush injury following the Marmara earthquake. They were hospitalized in 35 different hospitals having dialysis units in Istanbul, Ankara, Bursa, Eskişehir, Izmir and Samsun.

Subjects and methods

Patient information and data were obtained through special questionnaires sent out to all hospitals with dialysis units known to have admitted earthquake victims with renal problems. These questionnaires were prepared and distributed by the Marmara Earthquake Task Force of the Turkish Society of Nephrology (TSN) working in close collaboration with the Renal Disaster Relief Task Force representatives of the International Society of Nephrology (ISN) who had arrived Turkey just after the disaster.

Responses to questionnaires from the TSN Task Force were completed by the end of October 1999 and throughout this period, close contact by fax, telephone, and/or e-mail was maintained with most of the 35 hospitals involved in this study.

Population

The exact total number of injuries that required hospitalization is not known. But of the 43 953 injured victims [1], it was estimated that at least about 24 000 required some short- or long-term hospital care and/or treatment [2]. A total of 639 patients (291 women and 348 men) were hospitalized for acute renal failure (ARF) as a result of earthquake-related crush injuries, and they constituted roughly 2.6% of the hospitalized earthquake victims. Patients dead on arrival, patients with inaccurate records, patients with prior chronic renal disease, and patients who did not meet the diagnostic criteria for both crush syndrome and ARF were excluded from the study.

Data collection

Patient census data, complaints, diagnoses, injury types, details on clinical course, surgical interventions, frequency, amount and duration of dialysis, blood pressure, presence of fever and relevant laboratory findings were retrospectively evaluated from five-page questionnaires. For practical purposes, patients with crush injuries (patients who were injured by collapsed material and manifested muscle swelling and/or neurological disturbances in the affected section of the body) [13] and without prior chronic kidney disease who presented with azotaemia (BUN $\geqslant$40 mg%) and/or increased creatinine levels ($\geqslant$2 mg%) with or without oliguria and hyperkalaemia were considered as ARF cases as result of crush injuries. These patients constitute the subject of this report.

Data analysis

All data were evaluated using a Microsoft Excel 97 spreadsheet and SPSS v. 8.0 statistical software. To avoid duplication in the census data for patients admitted to more than one hospital, we reported only from the hospital that discharged the patient. However, for medical information

Table 1. Towns inhabited by patients at the time of earthquake: their populations and earthquake data [1,5,6]

	Population (1997 census) [5]	Earthquake intensity [6] (MSK)[a]	Buildings collapsed/ heavily damaged [1]	On spot death toll [1]	ARF patients with crush injury
Gölcük	76 566	X	12 310	5025	183
Sakarya	731 800	X	19 043	2629	169
Kocaeli	1 177 379	IX	19 315	4093	144
Yalova	163 916	IX–X	9462	2502	93
Others[b]	1 428 486	VII	17 167	1602	26
Not identified	–	–	–	–	29

[a]Medvedev-Sponhever-Karnik Scale (1964).
[b]Istanbul-Avcılar (n = 15), Bolu (n = 9), Eskişehir (n = 2) (respective populations: 214 621, 553 022, 660 843).

regarding admission, the records from both hospitals were equally considered.

Results

General features

Of the 639 patients admitted for ARF, 162 were not dialysed, 15 died before dialysis could be instituted, and 147 recovered without a need for dialysis. The remaining 477 patients (74.6%) received some form of dialytic therapy (Table 2). A total of 620 questionnaires revealed a mean age of 31.7 ± 14.7 years (range 0–90), and 71% of the patients were young adults within the age of 16–45 years. Age groups were as follows (in years): 0–15, 11.4%; 16–30, 40.9%; 31–45, 30.2%; 46–60, 13.8%; 61–75, 2.9%; 76–90, 0.61%.

Morbidity

Acute renal failure. Oliguria (53.2%), uraemia (94%), elevated creatinine levels (87%), hyperkalaemia (42%), hyperphosphataemia (63%), hypocalcaemia (83%), and high creatinine phosphokinase (CPK) levels (73%) were the most frequently encountered abnormalities related to the morbidity of ARF as a result of crush injury on admission. In the 340 patients with oliguria ($\leqslant 400$ ml/day) on admission, oliguria presented a mean duration of 11 ± 7.7 days, indicating a benign course and quick recovery from the underlying ARF (Table 3).

Traumatologic events. These are summarized in Table 4.

Medical problems.

(i) Infection and sepsis. Infection was reported in 223 patients (34.9%). The infections involved either the skin or soft tissue in 53 patients (8.3%), the lungs in 41 (6.4%), and the urinary tract in 14 (2.2%). Sepsis was observed in 121 patients (l8.9%). High fever ($\geqslant 37.5$°C) and leucocytosis ($\geqslant 10\,000/mm^3$) was seen in 38 (31.8%) and 82 (68%) patients, respectively (120 total). A mean systolic pressure < 70 mmHg was noted in 22 patients (3.7%) and it was strongly related to the presence of infection and/or sepsis. Interestingly, fasciotomy appeared to be a predisposing factor for development of sepsis (Table 5).

(ii) Haematologic problems. The mean haematocrit was 33.4 ± 9.1 (range 9.1–63.6), and low values ($\leqslant 30\%$) were observed in 116 patients. Disseminated intravascular coagulation (DIC) developed in 44 patients (6.9%). Thirty-seven patients (5.8%) had thrombocytopenia ($\leqslant 75\,000/mm^3$), which was severe in 11 patients ($\leqslant 50\,000/mm^3$) (Table 3).

(iii) Pulmonary problems. Acute respiratory distress syndrome (ARDS) was observed in 47 patients (7.3%). Pleural effusion was encountered in 22 (3.4%) patients and pulmonary thromboembolism and/or lung oedema in 23 (3.5%). Atelectasia was seen in two, chronic obstructive lung disease in two patients, pneumothorax in one, and asthma in one patient.

Table 2. Dialysis experience of ARF patients with crush injuries ($n = 639$)

Type of dialysis	Number of patients	(%)
Not dialysed	162	25.3
HD alone	437	68.3
HF alone	11	1.7
PD alone	4	0.6
HD + HF	21	3.5
HD + PD	2	0.3
PD + HF + HD	2	0.3

HD, haemodialysiis; PD, peritoneal dialysis; HF, haemofiltration.

Table 3. Means and standard deviations and range values for various parameters on admission in ARF patients with crush injuries

	Mean	± SD	Range	*n*
Quake to hospitalization interval (days)	3.38	3.16	1–28	602
Systolic blood pressure (mmHg)	128	26	40–240	592
Diastolic blood pressure (mmHg)	77	15	20–140	592
Urine volume on admission (ml/day)	748	1131	0–10 400	541
Duration of oliguria (days)	11	7.7	0–37	340
Fever (°C)	37.2	0.7	35.8–40	533
Haemotocrit (%)	33.4	9.1	9.1–63.6	594
Leucocytes (/mm^3)	14 571	6535	2400–50 100	558
Platelets (/mm^3)	179 820	93 705	8600–669 000	546
Albumin (g/dl)	2.6	0.7	1–5.2	446
BUN (mg/dl)	60.6	36.8	6–289	610
Creatinine (mg/dl)	4.48	2.95	0.3–19	609
Uric acid (mg/dl)	6.5	2.6	0.7–17.9	366
Potassium (mEq/l)	5.3	1.3	2.4–13.3	595
Calcium (mg/dl)	7.8	1.0	6.0–11.8	416
Phosphorus (mg/dl)	5.2	2.0	0.7–12.4	341
CPK (IU/ml)	23 443	45 778	60–459 800	320

Table 4. Traumatologic events in ARF patients with crush injury

Extremity injuries	520 (80.1%)
Extremity fractures	83 (12.9%)
Non-extremity fractures	59 (9.2%)
Extremity amputations	95 (14.9%)
Total fasciotomies	323 (50.5%)
Thoracic trauma	69 (10.8%)
Abdominal trauma	41 (6.4%)

Table 5. The role of fasciotomy in predisposing to sepsis

Sepsis	Fasciotomy		Total
	Not done ($n = 275$)	Done ($n = 243$)	
No	275 (87.0%)	243 (75.2%)	518 (81.1%)
Yes	41 (13.0%)	80 (24.8%)	121 (18.9%)
Total	316 (100.0%)	323 (100.0%)	639 (100.0%)

χ^2 Statistics: $P < 0.001$.

(iv) Cardiovascular problems. 435 patients (68%) were normotensive whereas 21 (3.2%) had low ($\leqslant$90 mmHg) and 135 (21.1%) had high ($\geqslant$150 mmHg) systolic blood pressures. Congestive heart failure was observed in 18 patients (2.8%). Hypervolaemia and hypovolaemic shock developed in four (0.6%) and three (0.46%) patients, respectively. Six patients (0.9%) had pericardial problems and nine others (1.4%) had various other cardiac problems.

(v) Gastrointestinal (GI) problems. There were only 23 patients (3.56%) with reported GI problems. Of these, 13 (56%) had GI bleeding and four (17%) developed gastroparesis. The remaining nine patients had various problems, including pancreatitis (two patients), subileus (two), ileus (one), and diarrhoea (one).

(vi) Neurologic and psychiatric problems. Thirty-one patients (4.8%) had peripheral neuropathy and 12 other patients (l.8%) manifested other neurologic problems, such as hypoxic encephalopathy (two), hemiplegia (one), paraplegia (one), convulsions (one), cerebral palsy (one). Finally, seven patients (1.1%) had depression which required psychiatric attention and/or drug therapy.

Mortality

Overall causes of death are summarized in Figure 1. A total of 97 patients (15.2%) died (50 of 348 male patients and 47 of 291 females). Mortality was not different according to gender ($P = 0.53$). In our ARF group, the percentage of older patients was strikingly small. Nevertheless, the age distribution of the on the scene fatalities remains unknown. The mortality rates of dialysed and non-dialysed patients were 17.2% (82 of 477) and 9.3% (15 of 162), respectively ($P = 0.015$).

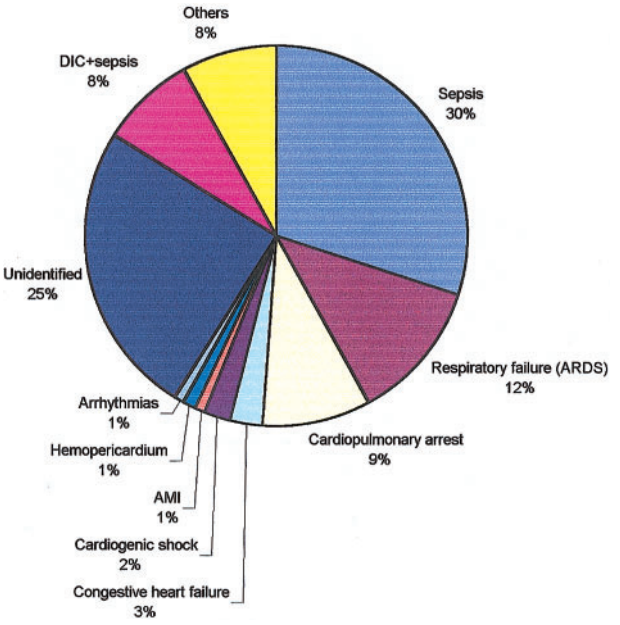

Fig. 1. Causes of death in the whole group.

As a group, patients who died had a significantly higher mean serum potassium level (6.0 ± 1.7 mEq/l) ($P < 0.001$) and a significantly lower mean serum albumin level (2.3 ± 0.7 g/dl) ($P < 0.01$) than the respective levels (5.3 ± 1.2 mEq/l and 2.6 ± 0.7 g/dl) in the survivors. In contrast, admission values for laboratory parameters closely associated with ARF, such as serum urea, creatinine and phosphorus, did not significantly differ between the dead and the survivors. The presence of oliguria was also not related to mortality ($P = 0.16$). Finally, factors directly linked to ARF and oliguria, such as hyperkalaemia and/or circulatory overload, played no major role in the mortality of the 15 patients who died before (Table 6).

Medical problems related to mortality

Univariate analysis revealed that traumatologic problems, sepsis (in 19% of patients), and problems such as high fever, hypotension, DIC, and thrombocytopenia (probably related to sepsis), all showed significant individual associations with mortality. The presence or development of ARDS and/or respiratory failure in 7.3% of patients, often in conjunction with sepsis, was also significantly associated with mortality (Table 7). However, multivariate analysis revealed that both DIC and ARDS, and/or respiratory failure, were frequently related to sepsis, and were the two major determinants of mortality (Table 8).

In the absence of sepsis, infection in general or infection localized to skin and soft tissue, pneumonia, urinary tract infection, and catheter infection had no significant association with mortality. Similarly, other medical problems including pulmonary thromboembolism, hypertension, congestive heart failure, and gastrointestinal problems all lacked a significant association with mortality.

Table 6. Causes of death in 15 patients who died before dialysis was started

Cause of death	Number of patients	Serum potassium (N/H)[a]
Sepsis	2	N and H (6.1 mEq/l)
Sepsis + DIC	2	N
Sepsis + ARDS	2	N
Sepsis + DIC + ARDS	2	N and H (8.9 mEq/l)
ARDS/lung failure	1	N
Cardiogenic shock and cardiac arrest	2	N
Hypovolaemic shock	1	H (6.5 mEq/l)
Hyperkalaemia to cardiac arrest + intracranial bleeding	1	H (8.4 mEq/l)
Retroperitoneal haemotoma	1	N
Cause unknown	1	H (6.0 mEq/l)

[a]N, Normal; H, High.

Trauma-related mortality

Mortality was significantly associated with thoracic and abdominal traumas, seen in 69 (10.8%) and 41 (6.4%) patients, respectively. It was also associated with amputations, performed in 95 (14.9%) of the patients with extremity traumas (Tables 6 and 7). The significant impact of thoracic and abdominal traumas in trauma-related mortality also persisted in the multivariate analysis (Table 7). Extremity traumas that did not require amputation and other traumatologic events such as head injuries, multiple injuries, and non-extremity fractures showed no significant association with mortality.

Similarly, despite high overall mean CPK values (Table 3) and rhabdomyolytic range (i.e. $\geqslant 1500$ U/l) in 74% of patients, these levels were not associated with mortality and were similar in both the dead ($23\,748 \pm 45\,672$ U/l) and in surviving patients ($24\,043 \pm 44\,790$ U/l).

Discussion

There are only a limited number of reports on ARF cases as a result of crush injury following major earthquakes. After the Armenian earthquake of 1988, at least 26 000 deaths and some 385 cases of ARF secondary to crush syndrome were registered, but documented cases with hospital records and follow-up were limited [9,10]. Following the Iranian quake of 1990, which resulted in 13 888 deaths, 43 390 injuries, and 33 615 hospitalizations, 154 cases of ARF required dialysis support, but only 30 of these cases were reported in any detail [11]. In the Hanshin-Awaji or Kobe earthquake of 1995, there were $\sim$5500 dead, and 41 000 injured, and 372 hospitalizations with crush syndrome. 202 of the latter patients developed ARF, requiring dialysis in 123 (61%). These patients were described in a detailed report based on hospital records [8].

The Marmara earthquake resulted in 17 479 deaths and 43 953 injuries. A total of 639 patients were hospitalized with detailed documentation of ARF-related crush injury. This number exceeds similar cases previously reported in conjunction with any single earthquake [7–11].

Our 639 cases with ARF corresponded to roughly 2.7% of the $\sim$24 000 earthquake-related hospitalizations. Interestingly, the 202 ARF cases in the Hanshin-Awaji earthquake also accounted for 3.3% of the 6107 hospitalizations. In the Iranian earthquake, which primarily affected rural areas, Atef *et al.* [11] reported an ARF incidence of only 0.5%. This is in line with previous observations showing a higher frequency of crush syndrome following earthquakes involved collapse of multi-storey buildings compared with those characterized by collapse of one-storey adobe and wood-frame structures [11,12].

Obviously, our ARF incidence was also strongly related to intensity of the earthquake. In fact, 584 (91.4%) of our patients came from four towns that had an earthquake intensity of IX–X on the MSK scale, and the death toll of 14 249 individuals (Table 1) in these four towns accounted for 81.4% of the total deaths despite their population of only 1 096 290 inhabitants, corresponding to only 13.5% of the total earthquake area population.

In the present series, the percentage of older patients was strikingly small. In fact, despite a population percentage of 8.4% in the Marmara Region for subjects >60 years, the same age group constituted only 3.5% of our patients [13]. Because the age distribution of the fatalities on the scene remains unknown, this small number may be related to previous observations that elderly people are more likely to sustain earthquake-related injury [14] but have a much higher on the spot fatality [15,16].

ARF resulting from rhabdomyolysis related to various causes had a reported mortality exceeding 40% [17]. Also, Atef *et al.* [11] reported a 40% mortality in 30 earthquake victims with ARF admitted to three teaching hospitals in Tehran [11]. In contrast, ARF mortality was 50 of 202 or 24.7% in the Hanshin-Awaji earthquake [8]. The overall mortality in our patients was 15.2%, a figure substantially lower than those cited above. It reached 17.1% in the dialysed patients but was 9.2% in patients not dialysed and suffering from a milder form of injury.

In the absence of abdominal or thoracic trauma or sepsis complicated by DIC or ARDS/respiratory failure, ARF *per se* did not appear to be a significant cause of death in our patients. Application of protective on the scene such as fluid administration, a reasonably short delay before hospitalization (a mean of 3.4 days following the earthquake), and the availability of equipment and staff to assure intensive and effective around the clock dialysis in almost all receiving hospitals seem to have contributed to this favourable result. In the 15 patients that died before dialysis could be started, factors directly associated with ARF, including hyperkalaemia and/or circulatory

Table 7. Traumatologic, surgical, and medical problems significantly associated with death according to univariate statistical anaylsis of two-way frequency tables

Type of problem	Group 1 ($n = 542$) (survivors)		Group 2 ($n = 97$) (non-survivors)		Chi-square statistics significance level
	with n (%)[a]	without n (%)[a]	with n (%)[b]	without n (%)[b]	
Amputation	66 (12.2%)	476 (87.8%)	29 (28%)	68 (70%)	$P < 0.0001$
Thoracic trauma	47 (8.7%)	495 (91.3%)	22 (22.6%)	75 (77.3%)	$P < 0.0001$
Abdominal trauma	26 (4.8%)	516 (95.2%)	15 (15.4%)	82 (84.5%)	$P < 0.0001$
Fever ($\geqslant 37.8^{\circ}C$)	98 (18%)	444 (81.9%)	26 (26.8%)	71 (73%)	$P < 0.05$
Sepsis	88 (16%)	454 (83.7%)	33 (34%)	64 (65.9%)	$P < 0.0001$
Lung problems	54 (10%)	488 (90%)	29 (28%)	68 (70%)	$P < 0.0001$
Respiratory failure and/or ARDS	24 (4.4%)	518 (95.5%)	23 (23.7%)	74 (76.2%)	$P < 0.0001$
Systolic hypotension (< 90 mmHg)	10 (1.8%)	532 (98%)	11 (11.3%)	86 (88.6%)	$P < 0.0001$
$\downarrow$ Mean arterial pressure (< 70 mmHg)	17 (3%)	525 (96.8%)	14 (14.4%)	83 (85.5%)	$P < 0.0001$
DIC	20 (3.7%)	522 (96.3%)	24 (24.7%)	73 (75.2%)	$P < 0.0001$
Thrombocytopenia ($< 75\,000/mm^3$)	20 (3.7%)	522 (96.3%)	17 (17.5%)	80 (82.4%)	$P < 0.0001$

[a]Percentages within Group 1 (survivors).
[b]Percentages within Group 2 (non-survivors).

Table 8. Logistic regression analysis of the association of various morbidity factors with mortality

(a) Traumatologic events ($n = 639$)[a]			(b) Medical problems ($n = 639$)[a]		
Parameters	P	Odds ratio	Parameters	P	Odds ratio
Extremity trauma ($\pm$)	0.37		Sepsis	0.26	
No. of extremities involved	0.22		Skin-soft tissue infection	0.34	
No. of extremity fractures	0.62		Pneumonia	0.94	
Fasciotomy ($\pm$)	0.88		Urinary infection	0.78	
No. of extremities with fasciotomy	0.11		Gastroenteritis	0.85	
Amputation ($\pm$)	0.23		GI bleeding	0.83	
No. of extremities amputated	0.06		Catheter infection	0.89	
Thoracic trauma	0.001	2.78	Infection, site unknown	0.76	
Abdominal trauma	0.0004	3.75	Respiratory failure and/ARDS	0.0001	4.53
Multiple trauma	0.17		Pulmonary thromboembolism	0.83	
			Lung oedema	0.49	
			Pleural effusion	0.34	
			DIC	< 0.0001	5.81
			Thrombocytopenia	0.82	
			Peripheral neuropathy	0.67	
			Depression	0.79	
			Hypertension	0.07	
			Congestive heart failure	0.1	
			Pericardial problems	0.76	

[a]P value of the model: < 0.0001.

overload played a minor role in mortality whereas sepsis, DIC, and ARDS were more important (Table 7).

Thoracic and abdominal traumas were seen in 10.8 and 6.4% of our patients, respectively. Amongst crush syndrome patients of the Hanshin-Awaji earthquake, Oda *et al.* [8] reported trunk injuries in 8.6% and associated abdominal injuries in 4.3% of patients.

In our patients, extremity traumas that did not require amputation and traumatologic events, such as head injuries, multiple injuries, and non-extremity fractures, including cranial, pelvic, and vertebral fractures had no association with mortality. Conversely, abdominal traumas and amputations were each significantly associated with mortality (Table 6). The significant weights of thoracic and abdominal traumas on trauma-related mortality were also confirmed by multivariate analysis (Table 8). Similarly, Oda *et al.* [8] reported a higher mortality with trunk involvement compared with crush injury to other anatomical sites following the Hanshin earthquake. In addition, injuries of the chest and abdomen constituted 42.4 and 21.2%, respectively, of fatalities that followed the Northridge earthquake [14].

Apart from ARF and traumatologic problems, our patients also had a wide spectrum of medical problems (*vide supra*). Of these, hypertension, congestive heart failure, pulmonary thromboembolism, gastrointestinal

problems, and infection uncomplicated by sepsis had no significant association with mortality. In contrast, sepsis and other problems, such as high fever, hypotension, DIC, and thrombocytopenia, were each significantly associated with mortality on univariate analysis. The presence or development of ARDS/respiratory failure in 7.3% of patients, often in conjunction with sepsis, and perhaps related to dust inhalation in some cases [18], also showed a significant association with mortality (Table 7). On multivariate analysis, however, only DIC and ARDS/respiratory failure emerged as significant determinants of mortality (Table 8). In fact, despite the availability of high quality intensive care in almost all instances, 50–54% of patients with DIC and/or ARDS/respiratory failure could not be saved.

As expected [19,20], fasciotomy was a significant predisposing factor for development of sepsis in our patients (Table 5). However, it showed no significant association with mortality (Table 8).

The proportion of patients with ARF requiring dialysis ranged from 20 to 60% [21–25]. Despite major advances in dialysis and intensive care, the mortality rate among patients with severe ARF requiring dialysis has not decreased appreciably over the past 50 years. Mortality rates in previously reported ARF outcome data ranged from $\sim 7\%$ among patients with prerenal azotaemia to $> 80\%$ in the patients with post-operative ARF [26,27]. When ARF occurs in patients with multi-organ failure, especially with severe hypotension or ARDS, the mortality rate ranges from 50 to 80% [27,29], and with the advent of dialysis the most common causes of death are sepsis, cardiovascular and pulmonary dysfunction, and withdrawal of life-support measures [28,29].

In conclusion, severe disaster and major earthquake patients should be rapidly transferred to undamaged peripheral general hospitals. When proper dialysis and intensive care facilities together with around the clock dedicated human effort are readily available, crush injury-related ARF patients have a lowed mortality. Mortality, when it occurred, was mainly associated with thoracic and abdominal trauma and medical problems such as DIC and/or ARDS/respiratory failure, often in conjunction with sepsis.

Members of the Turkish Disaster Study Group

Uludağ School of Medicine: Dr Kamil Dilek, Dr Osman Dönmez, Dr Mustafa Yurtkuran; Marmara School of Medicine: Dr Gülçin Kantarcı, Dr Çetin Özenen; İstanbul School of Medicine: Dr Rumeyza Kazancıoğlu, Dr Aydın Türkmen; Göztepe Social Security Hospital: Dr Hasan Erbil, Dr Bilgin Çapanoğlu; Kartal State Hospital: Dr Mehmet Çobanoğlu; Dr Necmi Kurt; Cerrahpaşa School of Medicine: Dr Süheyla Apaydın, Dr Rezzan Ataman; Dr Mehmet Rıza Altıparmak; Ankara School of Medicine: Dr Kenan Ateş, Dr Kenan Keven; GATA-Haydarpaşa Hospital: Dr Rıfkı Evrenkaya; Osman Gazi School of Medicine: Dr Haluk Kiper; GATA Ankara Hospital: Dr Müjdat Yenicesu; Ankara Numune Hospital: Dr Mansur Kayataş; Haydarpaşa Numune Hospital: Dr Funda Türkmen; Gazi School of Medicine: Dr Şükrü Sindel; Başkent School of Medicine: Dr Galip Güz; Bursa State Hospital: Dr Günay Okumuş; Ankara Social Security Etlik Hospital: Dr Murat Duranay; Bursa Social Security Hospital: Dr Celalettin Demircan; Hacettepe School of Medicine: Dr Yunus Erdem; Sisli Etfal Hospital: Dr Gülizar Manga; American Hospital: Dr Kemal Önen, Dr Moiz Bahar; Okmeydanı Social Security Hospital: Dr Vedat Çelik; Florence Nightingale Hospital: Dr Erhan Kabataş; Police Hospital: Dr Betül Öğütmen; Cerrahpaşa School of Medicine Pediatric Nephrology Department: Dr Lale Sever; Teacher's Hospital: Dr Ali Sarıbıyık; Metropol Hospital: Dr Sezer Sağlam; PTT Hospital: Dr Mustafa Çakçak; Samatya Social Security Hospital: Dr Mine Besler; İstanbul School of Med Pediatric Nephrology Department: Dr Aydan Şirin; Trakya School of Medicine: Dr Saniye Şen; Hacettepe School of Medicine Pediatric Nephrology Department: Dr Ayşin Bakkaloğlu; 19 Mayıs School of Medicine: Dr Nurol Arık; 9 Eylül School of Medicine: Dr Taner Çamsarı; MSF Turkey: Dr Fikri Kutlay. The following friends spent at least 1 week for saving lives: Belgium: Dr Heidi Hoeben, Dr Bruno Van Vlem, Dr Wim Van Biesen; Germany: Dr Ralf Schindler; France: Dr Dilaver Erbilgin.

References

1. The August 17 Kocaeli Earthquake. The Earthquake Research Department of the Ministry of Public Works and Settlement General Directorate of Disaster Affaires Web page: http://www.deprem.gov.tr/Kocaeli//info-Izmir-1.htm (updated on October 10, 1999)
2. Turkish Prime Ministry, Crisis Management Center: 'the 29 September 1999 Press Report'
3. Latest Situation in Damage Determination Work: Ministry of Public Works and Settlement Crisis Center, Ankara, September 29, 1999
4. Bağcı G, Yatman A, Özdemir S, Altın N. Damaging Earthquakes in Turkey. *Earthquake Investigation Bulletin* 1999; 69: 113–126
5. 1997 Population Census: Final Results. Republic of Turkey, Prime Ministry State Institute of Statistics (SIS) Web page: http://www.die.gov.tr/TURKISH/SONIST/NUFUS/
6. Özmen B. Equal Intensity Report. The Earthquake Research Department of the Ministry of Public Works and Settlement General Directorate of Disaster Affaires Web page: http://www.deprem.gov.tr/rapor/essiddet/ (downloaded on: 14 Feb. 2000)
7. Kuwagata Y, Oda J, Tanaka H *et al.* Analysis of 2,702 traumatized patients in the 1995 Hanshin-Awaji earthquake. *J Trauma Injury Infect Crit Care* 1997; 43: 427–432
8. Oda J, Tanaka H, Yoshioka T *et al.* Analysis of 372 patients with crush syndrome caused by the Hanshin-Awaji earthquake. *J Trauma Injury Infect Crit Care* 1997; 42: 470–476
9. Richards NT, Tattersall J, McCann M, Samson A, Mathias T, Johnson A. Dialysis for acute renal failure due to crush injuries after the Armenian earthquake. *Br Med J* 1989; 298: 443–445
10. Tattersall JE, Richards NT, McCann M, Mathias T, Samson A, Johnson A. Acute hemodialysis during the Armenian earthquake disaster. *Injury* 1990; 21: 25–28

11. 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
12. Noji EK. Prophylaxis of acute renal failure in traumatic rhabdomyolysis. *N Engl J Med* 1990; 322: 550
13. Percentage of population by age group: Turkey-Region, 1990. Republic of Turkey, Prime Ministry State Institute of Statistics (SIS) Web page: http://www.die.gov.tr/toyak 1/web demo 90-1
14. Peek-Asa C, Kraus JF, Bourque LB, Vimalachandra D, Yu J, Abrams J. Fatal and hospitalized injuries resulting from the 1999 Northridge earthquake. *Int J Epidemiol* 1998; 27: 459–465
15. Tanida N. What happened to elderly people in the great Hanshin earthquake. *Br Med J* 1996; 313: 1133–1135
16. Armenian HK. Deaths and injuries due to the earthquake in Armenia: a cohort approach. *Int J Epidemiol* 1997; 26: 806–813
17. Ward MM. Factors predictive of acute renal failure in rhabdomyolysis. *Arch Intern Med* 1988; 148: 1553–1557
18. Noji EK. Natural disasters. *Crit Care Clin* 1991; 7: 271–292
19. Better OS, Rubinstein I, Winaver J. Recent insights into the pathogenesis and early management of the crush syndrome. *Semin Nephrol* 1992; 12: 217–222
20. Michaelson M, Taitelma U, Bshouty Z, Bar-Joseph G, Bursztein S. Crush syndrome: experience from the Lebanon war, 1982. *Isr J Med Sci* 1984; 20: 305–307
21. Corwin HL, Teplic RS, Schreiber MJ, Fang LS, Bonventre JV, Coggins CH. Prediction of outcome in acute renal failure. *Am J Nephrol* 1987; 7: 8–12
22. Turney JH. Why is mortality persistently high in acute renal failure. *Lancet* 1990; 335: 971
23. Woodrow G, Turney JH. Cause of death in acute renal failure. *Nephrol Dial Transplant* 1992; 7: 230–234
24. Cameron JS. Acute renal failure—the continuning challenge. *Q J Med* 1986; 59: 337–343
25. Chertow GM, Chrisktansen C, Cleary PD, Munro C, Lazarus JM. Prognostic stratification in critically ill patients with acute renal failure requiring dialysis. *Arch Intern Med* 1999; 55: 155–11
26. Turney JH *et al*. The evolution of acute renal failure, 1956–1988. *Q J Med* 1990; 273: 83–104
27. Loh JW *et al*. A clinical index to predict survival in acute renal failure patients requiring dialysis. *Am J Kidney Dis* 1988; 11: 254–255
28. Wheeler DC *et al*. High risk acute renal failure. *Q J Med* 1986; 234: 977–984

Received for publication: 14.9.00
Accepted in revised form: 15.6.01