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The Marmara earthquake: Epidemiological analysis of the victims with nephrological problems

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Background. Crush syndrome resulting from earthquakes is a major cause of morbidity and mortality, as seen during the catastrophic Marmara earthquake that struck Northwestern Turkey in August 1999. This report analyzes the epidemiological characteristics of the crush syndrome victims of this disaster.

Methods. In order to analyze the nephrological problems caused by this earthquake, questionnaires were prepared within the first week of the disaster and sent to 35 reference hospitals that treated the victims. Data obtained by these questionnaires are the subject of this report.

Results. Of the 5302 hospitalized patients in reference hospitals, 639 (12.0%) suffered from nephrological problems, and 477 (9.0%) needed dialysis support. Considering the patients with renal problems, there was not any significant difference in gender; however, the incidence of children younger than 10 years and the older population (older than 60 years of age) was significantly lower as compared with the resident population of the affected area ($P < 0.001$). Nonsurvivors were older (34.5 ± 16.1 years) than survivors (31.2 ± 14.4 years, $P = 0.048$), while no deaths were recorded under the age of 10. Most patients (70.1%) were admitted within the first three days after the earthquake, and the mortality rate among these victims was higher (17.7%) as compared with victims admitted thereafter (10.0%, $P = 0.016$). The average time period under the rubble was 11.7 ± 14.3 hours, which was not significantly different between survivors and nonsurvivors, while the victims who required dialysis support spent shorter durations under the rubble, as compared with the ones who were not dialyzed at all (10.3 ± 9.5 vs. 15.9 ± 23.1 hours, $P < 0.001$).

Conclusion. Victims of catastrophic earthquakes are characterized by a high incidence of renal problems and the need for dialysis support. The incidence of nephrological problems is lower in children, while the period of time under the rubble is not a prognostic indicator of survival.

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Crush syndrome, followed by rhabdomyolysis, is a common cause of acute renal failure (ARF) after accidents or natural catastrophes. Among these, the earthquake is a leading causative factor of renal failure resulting in substantial morbidity and mortality [1–5]. In parallel with previous disasters, the Marmara earthquake, which struck Northwestern Turkey in August 1999, was characterized by a high incidence of ARF.

Although many major earthquakes have occurred all over the world over the past 20 years, detailed reports describing epidemiological, clinical, and laboratory features and final outcome of the victims suffering from ARF are presently lacking [2, 6]. Since medical and surgical complications encountered in the disaster victims affect almost all organs and systems, this lack of data is a problem not only for nephrologists, but also for other specialists such as internists, cardiologists, traumatologists, general surgeons, infectiologists, as well as for general practioners and epidemiologists.

Our study documents the epidemiological features of the victims who suffered from acute renal problems caused by the Marmara earthquake.

METHODS

The disaster

The Marmara region of Turkey was devastated by one of the most catastrophic earthquakes of the world in this century, registering 7.4 magnitude on the Richter Scale, on August 17, 1999, at 3:01 a.m. The Marmara region, a densely populated and highly industrialized area, is located in the northwestern part of the country, and includes some major cities, such as Adapazarı, Gölcük (the epicenter of the disaster), Kocaeli, Yalova, İstanbul, and Eskişehir, with a total number of inhabitants of approximately 20,000,000 [7]. All of these cities are situated close to the North-Anatolian Fault Zone, which has been the location of many catastrophic earthquakes during the last century [8].

In the affected cities, many multistory buildings completely collapsed during the primary event, while multiple aftershocks following the initial shock caused a complete collapse of many of the partially destroyed buildings.

Since the earthquake occurred during the very early hours of the day while most of the inhabitants were indoors, it resulted in a substantial morbidity and mortality. According to the official reports, the disaster caused 17,480 deaths and 43,953 wounded [9], while the locally estimated mortality was even higher. Approximately 600,000 people became homeless because 133,683 homes were partially or completely destroyed [9].

The aftermath of the disaster was characterized by the destruction or disorganization of most of the facilities such as electrical power and water supply, fire service, telecommunication, hospital infrastructure, and patient transport. Also, the main highways from the disaster area to the health facilities of Ankara and İstanbul were damaged. As a result, at least during the first two days of the disaster, transportation by road could hardly be accomplished.

Relief efforts

Although rescue efforts started immediately after the earthquake, there was a major shock and panic, not only in the cities affected by the earthquake, but also all over the country, making early interventions for rescue activities confused and partly inefficient.

The rescue activities were (mainly) organized by the Turkish army, whereas civilian national and international rescue teams made enormous efforts toward saving lives [10–12].

Since almost all of the hospitals situated in the disaster area were partly or completely destroyed, victims were transferred by boat, helicopter, or road to 35 reference hospitals located in adjacent cities such as İstanbul, Bursa, Eskişehir, and Ankara.

Table 1. Reference hospitals that treated earthquake victims and responded to the questionnaires (the number of patients with renal problems and the victims who needed dialysis support at these hospitals is also provided)

Name of the Hospital	Patients with renal problems	Patients dialyzed
İstanbul		
Marmara Med. Fac.	83	53
İstanbul Med. Fac.	60	40
Göztepe Social Security Hosp.	55	40
Kartal State Hosp.	35	25
Cerrahpaşa Med. Fac.	33	22
GATA-Haydarpaşa Hosp.	25	23
Haydarpaşa Numune Hosp.	19	18
Şişli Etfal Hosp.	11	8
Bursa		
Uludağ Med. Fac.	70	53
Uludağ Med. Fac. (pediatrics)	17	4
Bursa State Hosp.	16	16
Bursa Social Security Hosp.	10	6
Ankara		
Ankara Med. Fac.	27	22
GATA Ankara Hosp.	23	22
Ankara Numune Hosp.	21	16
Etlik Social Security Hosp.	13	9
Gazi Med. Fac.	17	15
Başkent Med. Fac.	16	16
Hacettepe Med. Fac.	10	10
Eskişehir		
Osman Gazi Med. Fac.	24	24
Different cities		
Other (15) hospitals	54	35
Total	639	477

Only the hospitals that have recorded more than 10 patients in the questionnaire are shown. Data indicate the number of patients reported in the replies to the questionnaire.

Abbreviations are: Med. Fac., Medical Faculty; Hosp., Hospital; Patients dialyzed, patients who were treated by any form of renal replacement therapy.

Data collection regarding nephrological problems

As can be expected, the disaster resulted in hundreds of cases of ARF due to rhabdomyolysis. To analyze the severity and magnitude of the problem, The Turkish Society of Nephrology (TSN) in collaboration with the Renal Disaster Relief Task Force (RDRTF) of The International Society of Nephrology (ISN) prepared specific questionnaires within the first week of the disaster. These questionnaires were sent to the nephrology units of 35 reference hospitals that treated the victims (Table 1). Twenty-three of these hospitals were located in cities close to the epicenter, which by themselves had been partially affected by the earthquake (İstanbul, Bursa, Eskişehir); nine hospitals were located in Ankara, which was 300 km away from the epicenter and not affected by the disaster. Also, some victims were treated in three hospitals in different regions of Turkey and far from the epicenter. The centers were asked to fill in the questionnaires and to return them only after discharging or transferring their last patient.

Because of logistic and medical reasons, some patients were transferred from one reference hospital to another during the hospitalization period. To avoid repetition in the census data, duplicate records were counted only in the list of the last hospital where the patient was located. Patients who had established chronic renal failure before the earthquake were excluded from the analysis.

Definitions

For the purpose of this analysis, the following definitions were used.

Reference hospitals: Secondary or tertiary care centers that had a sufficient number of critical care beds with advanced equipment, such as dialysis and intensive care units, and experienced medical and surgical teams.

Crush injury: Patients who were injured by collapsing material and debris, and manifested muscle swelling and/or neurological disturbances in the affected part of the body [13].

Crush syndrome: Patients with crush injury and systemic manifestations [14]. For the purpose of the present analysis, only the victims with nephrological problems attributable to the crush injury were considered.

Nephrological problem due to crush injury: Patients who had crush injury and one of the following characteristics: oliguria (urinary output <400 mL/day), elevated levels of blood urea nitrogen (BUN) (>40 mg/dL), serum creatinine (S_{Cr}) (>2.0 mg/dL), uric acid (>8 mg/dL), potassium (K^+) (>6 mEq/L), phosphorus (P) (>8 mg/dL), or decreased serum calcium (Ca^{2+}) (<8 mg/dL).

Polyuria: Daily urinary output of more than 2000 mL.

Dialyzed patients: Victims treated at least once by any form of renal replacement therapy, including intermittent hemodialysis, peritoneal dialysis, continuous arteriovenous or venovenous, hemodialysis, or hemo(dia)-filtration.

The indications for renal replacement therapy were defined by the attending nephrologists of the reference centers.

The questionnaires

The questionnaires, which had been designed to register medical data, contained five pages, including the definitions and the tables.

The first (introductory) page of the questionnaire defined the terminology, while each of the remaining four pages contained tables that consisted of multiple rows (each row representing one patient), and 63 cells per row, each of which represented a clinical or a laboratory parameter.

The second page included general demographic data such as name, age, gender, date of admission, medical problems before the earthquake, the city where he/she experienced the disaster, duration under the rubble, reference center, degree and type of injury, type of surgical interventions, medical complications, and non-nephrological medical therapeutic interventions.

Page three contained cells for the admission data, including blood pressure, pulse rate, body temperature, urine output, blood biochemistry [BUN, S_{Cr}, uric acid, K^+, Ca^{2+}, P, creatine phosphokinase (CK), alanine aminotransferase (ALT), aspartate aminotransferase (AST), lactic dehydrogenase (LDH), albumin)], blood cell count, and abdominal ultrasonography.

The fourth page included information about the nephrological interventions, such as the type and volumes of fluids during the first hospital day, minimum and maximum urinary volume during the hospitalization period, time period of oliguria and polyuria. Features of renal replacement therapies (if any), such as the number of hemodialysis sessions, number of days that the patient needed hemodialysis support, the volume of peritoneal dialysate, the number of days on peritoneal dialysis, the number of hemofilters that had been used for slow continuous renal replacement therapies, and the number of days on that support were noted in this page as well. Features of transfusion therapy (if any), such as the number of blood transfusions or transfusions of any other blood product such as fresh frozen plasma or human albumin, also were provided on this page.

The results of the bacteriological examinations (urine, wound, drainage material samples), the highest numbers for BUN, serum creatinine, uric acid, K^+, Ca^{2+}, P, CK, ALT, AST, LDH, leukocyte, and platelet counts and the lowest numbers for hemoglobin, hematocrit, Ca^{2+}, P, total serum protein and serum albumin, the result of the kidney biopsy (if performed), S_{Cr} at the moment of discharge, and final outcome of the patient (if fatal, the cause of death needed to be included) were asked on the last page.

Most of the reference hospitals returned the completed document within the first three months of the disaster. In total, information regarding 681 patients was received. Following the exclusion of duplicate records and the elimination of three chronic renal failure patients, 639 sets of data were subjected to analysis.

After the questionnaires were received, repeated telephone communications were performed to define the definite outcome of the patients who had been transferred from the nephrology centers to other clinical departments (such as plastic and reconstructive surgery, physical therapy, rehabilitation, or orthopedics).

The present article deals with only the epidemiological aspects. Other data obtained from the questionnaire are the topic of additional publications.

Statistical analysis

Descriptive statistics for all numeric variables, including means, medians, standard deviations, and minimum and maximum values, together with the proportions of all categorical variables, were calculated. Two independent group means were compared by the Student *t* test. If the

Table 2. Number of patients meeting each of the inclusion criteria

Criteria	Dialyzed patients ($N = 477$)	Non-dialyzed patients ($N = 162$)	Total ($N = 639$)
Urinary volume, *<400 mL/day*	300 (398) (75%)	18 (146) (12%)	318 (544) (58%)
BUN, *>40 mg/dL*	382 (450) (85%)	98 (160) (61%)	480 (610) (79%)
S_{Cr}, *>2 mg/dL*	413 (450) (92%)	73 (159) (46%)	486 (609) (80%)
S_K, *>6 mEq/L*	152 (437) (35%)	12 (158) (8%)	164 (595) (28%)
S_{UA}, *>8 mg/dL*	83 (295) (28%)	7 (87) (8%)	90 (382) (24%)
S_P, *>8 mg/dL*	29 (271) (11%)	— (70) (—%)	29 (341) (9%)
S_{Ca2+}, *<8 mg/dL*	185 (295) (63%)	45 (95) (47%)	230 (390) (59%)

Not all the parameters were specified in the questionnaires for every patient; hence for each parameter "*N*" figures varied. Numbers in parentheses indicate the total number of each parameter specified in the questionnaires. Thus, for example, considering the dialyzed patients, 75% (300/398) were admitted with urine volumes less than 400 *mL/day*.

Abbreviations are: Dialyzed patients, patients who received any form of renal replacement therapy; Non-dialyzed patients, patients who did not need dialysis support; S_{Cr}, serum creatinine, S_K, serum potassium, S_{UA}, serum uric acid; S_P, serum phosphorus; S_{Ca2+}, serum calcium.

group variances were not homogenous as evidenced by the Levene test, the *P* values were adjusted. Differences between group proportions were examined by the χ^2 test. In 2 × 2 contingency tables, when expected values in the cells were found to be less than two in any cell or less than five in more than half of the cells, the Fisher exact test was used, instead of the χ^2 test.

Correlations between numeric variables were examined by Pearson simple correlation coefficients. For the analysis of the prediction of death, first univariate tests (Student *t* test for independent groups for numeric variables and χ^2 test for categorical variables) were performed. Different logistic regression models were then built, and possible predictors were examined. Variables related to patient demographics were examined by different models.

Statistical significance was accepted at *P* values less than 0.05.

RESULTS

By the date the questionnaires were sent, daily telephone calls were made to the reference hospitals by the local coordinator (M.S.S.) for updating the data. These calls concerned logistical information considering the needs of dialysis material and personnel at each center, as well as the numbers of crush patients, dialyzed victims, deaths, and the number of discharges. Therefore, the flow of the victims could be monitored carefully. Since these data were faxed to the chairman of RDRTF European Branch (N.L.) twice weekly, the international nephrology community could follow this catastrophic renal disaster very closely.

Taken as a whole, 9843 patients were admitted to reference hospitals; 5302 of them were hospitalized and 425 died (overall mortality rate of 4.3%). Considering all hospitalizations, the number of patients with renal problems was 639, of whom 477 (74.6%) were treated by dialysis. Accordingly, 12.0% of all hospitalized patients developed renal problems, and 9.0% needed renal replacement therapy.

The number of victims meeting each of the inclusion criteria of the analysis is provided in Table 2. Since many patients conformed to more than one criterion, the total number of the patients who met each criterion exceeded 639. There was a slight predominance of males, since 348 (54%) of the 639 victims with renal problems were males compared with 291 (46%) females. Of the male patients, 50 (14.4%) died, while 47 (16.2%) deaths were noted amongst the females ($P = 0.53$).

The mean overall age was 31.7 ± 14.7 (range of 0.3 to 90) years, and most of the victims with nephrological problems (69.3%) belonged to the age categories between 10 and 40 years (Fig. 1).

According to the national statistics, 18.7% of the inhabitants of the affected cities were younger than 10 years old before the earthquake [7], while only 1.9% of the victims with renal problems in the present series were younger than 10 years of age (Fig. 1 and Table 3). A similar discordance was noted also in the older population; the proportion of inhabitants older than 60 years of age was 8.4%, while only 4.3% of the victims with nephrological problems belonged to this age group. Age-stratified numerical and normalized figures on the basis of inhabitant population for both crush syndrome patients and deaths are provided in Table 3. Regarding the normalized figures per 100,000 inhabitants, a significant difference was noted in crush syndrome rate between different age strata ($P < 0.0001$), with the highest incidence between 20 and 59 (Table 3). A positive linear correlation between the proportion of crushed patients and mean age per stratum was noted ($P < 0.0001$). Similar, albeit somewhat less pronounced, trends were noted regarding the mortality rate in general and the mortality rate of crush syndrome ($P < 0.0001$ and $P = 0.03$), and a linear positive correlation was found here as well ($P = 0.001$ and $P = 0.03$).

Nonsurvivors were older (34.5 ± 16.1, range of 12 to 87 years old) than the survivors (31.2 ± 14.4, range of

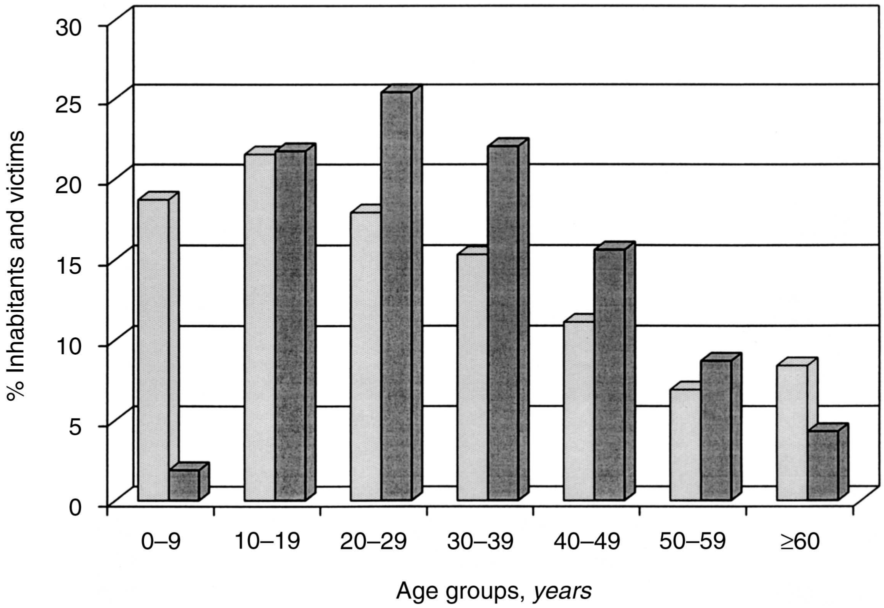

Fig. 1. Age distribution of the inhabitants (■) and of the victims with nephrological problems (■).

Table 3. Age-stratified numerical and normalized data per number of inhabitants for both crush syndrome patients with nephrological problems and deaths (data are statistically compared to the age stratum [30–39] as a reference)[a]

Age group	Population	*N* crush patients	*N* deaths	Crush rate per 100,000	Mortality rate per 100,000	Mortality rate for crush patients, %
0–9	388,130	12	0	3.1[c]	0.0[c]	0.0
10–19	436,409	122	12	28.0[b]	2.7	9.8
20–29	371,750	145	25	39.0	6.7	17.2
30–39	318,517	125	12	39.2	3.8	9.6
40–49	238,881	91	12	38.1	5.0	13.2
50–59	143,986	51	9	35.4	6.3	17.6
60+	175,420	26	8	14.8[c]	4.6	30.8[b]
Global	2,073,093	572	78	27.6	3.8	13.6
Significance between different age strata				$P < 0.0001$	$P < 0.0001$	$P = 0.03$
Linear correlation between age groups and incidence of crush syndrome or death				$P < 0.0001$	$P = 0.001$	$P = 0.03$

[a] Data related to Istanbul are not included in this table, since only a small part of the city was affected by the earthquake
[b] $P < 0.01$; [c] $P < 0.001$ vs. age 30–39

0.3 to 90 years old, $P = 0.048$). While no deaths were recorded for the victims under the age of 10, 8 deaths were noted in 26 (30.8%) patients older than 60 (Table 3).

The dates of admission of the victims to the reference hospitals were identified in 603 of the questionnaires (Fig. 2). According to these data, 423 (70.1%) of the patients were admitted to reference hospitals within the first three days of the disaster. By the end of the first week, 562 (93.2% of all patients) had been admitted. In the univariate analysis, the mortality rate was 17.7% (75 out of 423) in the victims who were admitted within the first three days following the earthquake, whereas this rate was 10.0% (18 out of 180) for those who had been admitted later on ($P = 0.016$).

The victims were mainly inhabitants of four cities: Gölcük, Adapazarı, Kocaeli, and Yalova. The number of victims and deaths normalized for the inhabitants per city is provided in Figure 3. The normalized numbers for being crushed and mortality rates of crush syndrome patients in these cities were found to be significantly different ($P < 0.0001$) for both parameters. The highest number of victims came from Gölcük (epicenter of the disaster), although this city had the lowest population among the affected cities (Fig. 3). The mortality rates among crush patients were also significantly different between the cities ($P = 0.02$); the highest mortality rate was reported among the victims coming from Yalova (23.7%).

The duration of time spent under the rubble was 11.7 ±

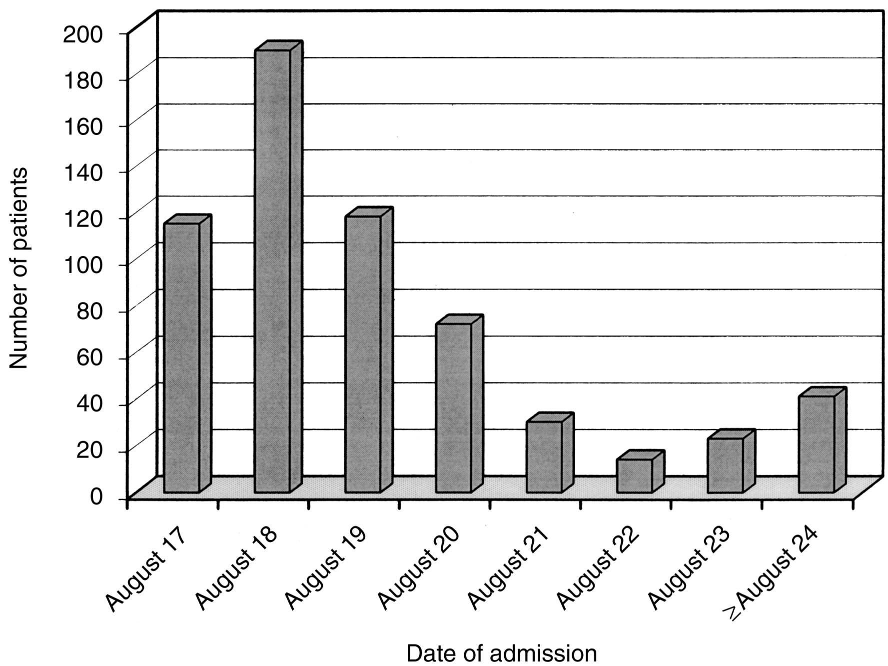

Fig. 2. Dates of admission to the reference hospitals. This parameter was specified in 603 of the questionnaires. By the end of the first week, more than 90% of all patients had been admitted.

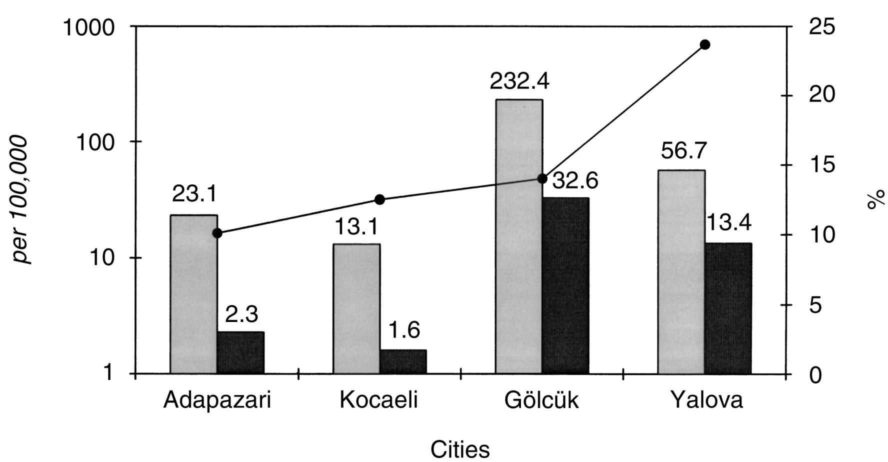

Fig. 3. Normalized crush syndrome rates (▒) and mortality rates per city (■), and mortality rate in the crush syndrome patients (●). The population of the cities are as follows: Adapazarı, 731,800; Kocaeli, 1,100,793; Gölcük, 76,585; Yalova, 163,915; total, 2,073,093). Crush syndrome rate and mortality rate (left axis), and mortality rate in crush syndrome patients (right axis). A logarithmic scale has been used in the left *y* axis.

14.3 (range 0.5 to 135) hours ($N = 539$), and the victims who spent the longest times stayed there for 135, 120, and 98 hours, respectively. Remarkably, of these three, only the second patient (who remained buried for 120 hours) was dialyzed and eventually died, while the first and the third patients survived without any dialysis support. The number of the extricated victims stratified according to the time period under the rubble is provided in Figure 4.

The time period for nonsurvivors was 13.7 ± 17.0 (range 0.5 to 120) hours, while the same period for survivors was 11.5 ± 14.0 (0.5 to 135) hours ($P = 0.26$). The duration in the victims who required dialysis was shorter (10.3 ± 9.5, range 0.5 to 120 hours) as compared with those who were not dialyzed (15.9 ± 23.1, range 0.5 to 135 hours; $P < 0.001$).

No correlation was noted between age and duration spent under the rubble ($P = 0.25$, $r = 0.05$). On the other hand, the time period under the rubble before extrication predicted the number of both fasciotomies ($P = 0.001$, $r = 0.142$) and amputated extremities ($P < 0.001$, $r = 0.264$).

In a multivariate analysis model, including the variables of age, gender, date of admission, the cities where the disaster was experienced, and the time period under the rubble, age was found to be a predictor of death ($P = 0.02$, OR = 1.02 per year). On the other hand, in this model, no associations were found between mortal-

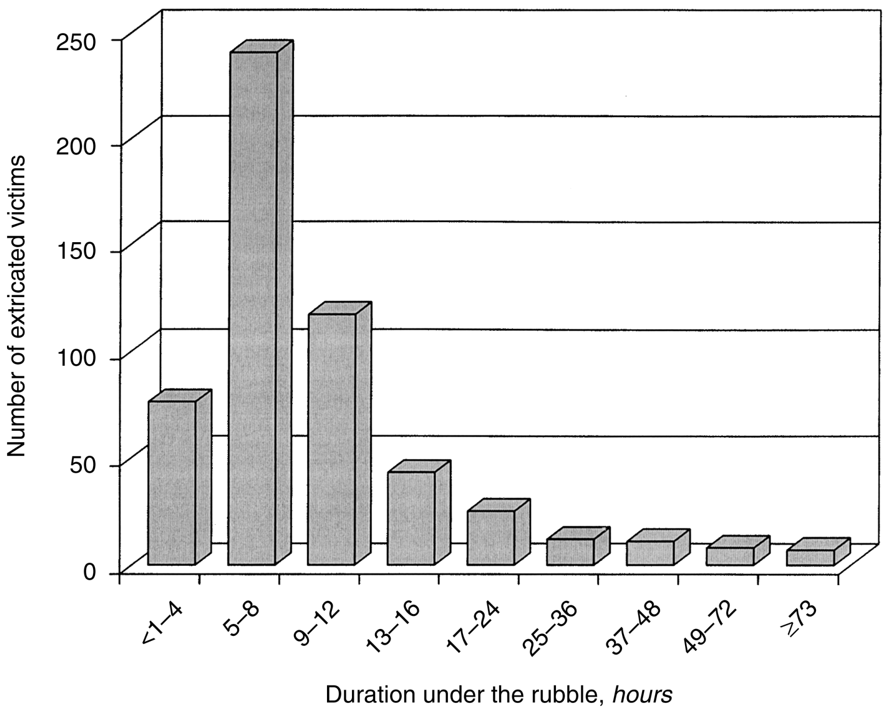

Fig. 4. Number of the extricated victims according to stratified durations of time under the rubble.

ity and gender ($P = 0.64$), time spent under the rubble ($P = 0.22$), date of admission ($P = 0.08$), or the cities where the disaster was experienced ($P = 0.54$).

DISCUSSION

Although more than 50 years passed since the first modern description of crush syndrome during the Second World War by Bywaters and Beall [15], the number of reports describing in detail the fate of renal failure patients following crush injury in natural and man-made disasters is still scarce [2, 6]. The cause for the scarcity of these scientific data is probably due to incomplete recordings attributable to the chaotic circumstances immediately after the disaster, heavy workload during these days, and panic. Also, various other (scientific, bureaucratic, political, social, and/or psychological) factors might play a role.

Our study offers a detailed documentation of the fate and profile of patients with nephrological problems after a disaster of great magnitude, thanks to the high response rate to the questionnaires. This favorable cooperation of the centers can be explained on the basis of (*1*) sending the questionnaires within the first week of the disaster and early response, (*2*) well-organized national and international commitment, and (*3*) feelings of close collaboration with local and international civilian organizations, mainly due to the moral support offered by these teams beginning from the early hours after the disaster [12].

However, this analysis still has some drawbacks, since the answers to many of the requested variables in the questionnaires are incomplete. The main reason for this lack of information could be the missing data in some of the patient records attributable to the chaotic disaster conditions, as has been mentioned in nonrenal populations [5, 16, 17].

The Marmara earthquake is, to our knowledge, the disaster with the largest documented nephrological population, and it included 639 patients with renal problems of whom 477 needed dialysis support. In the best documented severe earthquake to date, the Kobe disaster in Japan, 202 patients with ARF and 123 patients who needed dialysis were reported [13, 17].

The incidence of crush syndrome following major earthquakes has not been well defined; and numbers varying from 2 to 5% of all traumatized patients have been described [18]. Also, information regarding the incidence of ARF based on the crush syndrome is scarce. Of the 2702 traumatized patients during the Kobe earthquake, 372 (13.8%) were complicated with crush syndrome, and 202 (7.5%) suffered from ARF [13]. In our series, the 12% incidence of acute renal problems when all hospitalized victims are considered is an even higher number. However, in the present database, information was collected only from the reference hospitals, and since many of the victims admitted to these particular centers had a complicated course, our study population may not represent objective demographic characteristics of all disaster victims. Even a higher figure has been reported during the analysis of the Armenian earthquake. In that series, which also was restricted to the global hospital admissions, ARF was reported in 23% of all victims [19]. In view of the quite complete numbers offered by the present analysis, taking into account all hospitalizations, a percentage of 10 to 20% of the victims developing acute renal problems related to the crush syndrome seems more realistic.

The highest normalized rates of crush syndrome were observed in patients between the ages of 20 and 59 (Table 3). This finding should not be surprising, since victims within these age strata have larger muscle mass and hence are more heavily faced with the pathophysiological consequences of rhabdomyolysis. On the other hand, in the present series, there was a surprising difference in the age pattern of the general inhabitants population as compared with the age pattern of the renal victims. While 18.7 and 8.4% of the population in the disaster area were under 10 years or older than 60 years of age [7], only 1.9% of the victims with renal problems were younger than 10, and 4.3% were older than 60 (Fig. 1). It is possible that most of the older victims died immediately during the earthquake, since this age group may be more prone to both trauma and death during disasters [20–23]; hence, they do not appear in the present series. On the other hand, the reports regarding the prognosis of children are contradictory. During the Kobe earthquake, although the best prognosis was observed in the victims between 30 to 39 years old, the mortality rate in children was also favorable [21]. During the Guatemalan earthquake, few fatalities were younger than 20 years of age [22]. According to the latter report, death in children was inversely correlated to age with the exception of the very young children, probably because they slept together with their parents [22].

In the present series, the rates of both crush syndrome and mortality in children are remarkably low. Whether the children could not survive similarly to the older population, or on the other hand, had better chances to survive even in small spaces thanks to their low body surface area remains a matter of debate.

Triage practices are of vital importance during mass disasters. In our case, the first triage was made at the disaster field and the victims were referred to reference hospitals by means of helicopters and ambulances and, for Istanbul, by boats. The nearest hospital to the epicenter received the highest number of victims, that is, Uludağ School of Medicine (Bursa) and Marmara School of Medicine (Istanbul), both of which were as close as a one hour ambulance drive to the epicenter. The second triage was made at the emergency units of the hospitals. The local coordinator provided frequent updates by telephone and fax communication with regards to the available facilities with dialysis machines and patient beds to the overwhelmed hospitals. Public hospitals were asked to refer the seriously injured and complicated victims to university hospitals with available beds. Because the updated daily information was collected at the local coordinator's office, it was possible to prevent most of the chaos, at least at the level of nephrology units of the reference hospitals. As pediatric nephrology units also were present in the four major cities, children under the age of 15 were referred to these units. However, since the number of children was quite low in the present series, many pediatric units treated only a few victims.

In earthquakes, most hospital admissions occur within the first three days after the disaster [5, 20, 24]; in accordance with this hypothesis, only 2.4% of the 902 patients were admitted seven days or more after the Armenian earthquake [3]. In our series, a similar trend was observed: of the 603 patients in whom the date of admission was specified, 423 (70.1%) and 562 (93.2%) were admitted at the latest three and seven days after the disaster, respectively. This report includes data recorded only by the reference hospitals; hence, the possibility that a number of patients were admitted with a certain delay from other primary care centers should be considered. In the light of these numbers, one may speculate that only very few patients with renal problems will be admitted after the first week of a disaster. Therefore, logistical plans for using hospital resources should be made on this basis.

Most of the admissions for renal failure and deaths were from a relatively small town, Gölcük, which was the epicenter of the disaster. As can be expected, living at the epicenter of an earthquake is certainly a major risk factor for injuries and deaths, which has been pointed out earlier during the Armenian earthquake [23].

During the Kobe earthquake, a higher mortality rate was observed in the patients who were treated in hospitals of the affected area compared with those transported to undamaged hospitals in the surrounding area [17]. This message underlines the importance of patient referral from the disaster field to surrounding health facilities. However, transportation by road is always a problem early after major disasters due to broken roads and bridges, which was also the case during the Marmara earthquake. On the other hand, the unique geography of the Marmara region offered an advantage in that these victims could be transported by ferry boats across the Marmara Sea, which might have had a favorable effect on the final outcome.

Interestingly, this capability for sea transportation may have affected the mortality rate due to a selection bias. In the present series, although the absolute numbers were smaller than for Gölcük, the highest relative mortality rate was noted among victims coming from Yalova, a resort city on the Southern coast of the Marmara Sea. Since most of the reference hospitals were located in İstanbul, a fast (within 1 hour) transport of seriously injured victims from Yalova was possible by boat while they were still alive. However these particular victims may have died in the early period of hospital admission, giving rise to higher rates of mortality, as has been suggested previously [17]. On the other hand, many severely injured victims in the other cities probably could not survive long enough to reach the hospitals. In accordance with this hypothesis, the mortality rate of the patients who had been admitted within the first three days was higher (17.7%) than for those who had been admitted thereafter (10.0%, $P = 0.016$).

In the Marmara earthquake, time period under the rubble (11.7 ± 14.3 hours) was longer than for the Kobe (9 ± 13 hours) and Erzincan (9 ± 5 hours) earthquakes, the latter one being another recent seism in Eastern Turkey [13, 25]. The magnitude of the Marmara earthquake was more severe than those for Kobe and Erzincan as well, so the rescue teams may not have been able to cope as efficiently with the extrication needs during the first hours of the disaster.

It has been suggested that for the development of crush injury, continuous pressure on the muscles of at least four hours is necessary [6], although shorter periods such as one hour during the Kobe earthquake have been recorded [13, 26]. In the present series, there were patients rescued within the first hour of the disaster who still suffered from crush syndrome, suggesting that this syndrome may develop in time periods less than one hour.

There is no doubt that most of the deaths occur immediately after the earthquakes [27, 28], and of those still alive, short-term mortality dramatically increases as the time period buried under the rubble lengthens [3, 18, 29]. Our findings showed that, despite a shorter duration under the rubble for survivors (11.5 ± 14.0 hours) compared with victims who eventually died (13.7 ± 17.0), this difference was not significant ($P = 0.26$). Surprisingly, in the present series, there was a negative association between the time period under the rubble and admission serum creatinine values together with less dialysis needs (unpublished data). It is notable that two of the three victims who spent the longest time (98 and 135 hours) under the rubble improved with conservative treatment and did not require dialysis at all. It can be speculated that the victims who were only mildly injured could have survived longer under the rubble and may have been rescued even four or five days after the disaster. As a result, the long time periods before extrication of these victims may give rise to a selection bias.

To summarize, the present epidemiological analysis indicates that particular features such as the crush syndrome may develop within a very short duration, and that the time period spent under the rubble is not an indicator of survival at least during the first five days of the disaster. The incidence of children younger than 10 is lower as compared with the inhabitant population. The older population is at an increased risk of death. Most of the patients are admitted within the first three days of the disaster, and the mortality rate among the victims admitted within this time period is higher. All of these findings may help to prioritize rescue activities, to effectively apply the available resources, and to improve the outcome of the victims at the occasion of future massive disasters. This detailed analysis also may be relevant for all kinds of disaster planning, beyond the field of nephrology.

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