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Original Article

Clinical findings in the renal victims of a catastrophic disaster: the Marmara earthquake*

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Abstract

Background. The clinical course of acute renal failure (ARF) related to crush syndrome is very complex, because of co-existing surgical and/or medical complications. After the devastating Marmara earthquake that struck Turkey in August 1999, 639 patients were identified with nephrological problems, whose clinical findings have been the subject of this analysis.

Methods. Specific questionnaires asking about 63 variables were sent to 35 reference hospitals that treated the victims. Clinical findings of the renal victims were analysed.

Results. At admission, high fever was noted in 31.8% of the patients; the temperature of non-survivors was higher ($P=0.027$). Mean blood pressure was higher in survivors ($P=0.004$) and dialysed victims ($P<0.001$). Most (61.4%) patients were oligo-anuric; oliguria lasted for 10.8 ± 7.2 days. Thoracic and abdominal traumas were associated with a higher risk of mortality. 397 fasciotomies and 121 amputations were performed in 790 traumatized extremities. Fasciotomies were associated with sepsis ($P<0.001$) and dialysis needs ($P<0.0001$), while amputations were associated with mortality ($P<0.0001$). Medical complications, which were associated with dialysis needs ($P<0.0001$) and mortality ($P<0.0001$), were observed in 51.5% of patients. In a multivariate analysis model of medical complications, disseminated intravascular coagulation (DIC) ($P<0.0001$, OR$=5.81$), and adult respiratory distress syndrome (ARDS) ($P=0.0001$, OR$=4.53$) were predictors of mortality.

Conclusions. In the aftermath of catastrophic earthquakes, clinical findings of the renal victims can predict the final outcome. While fasciotomies indicate dialysis needs, extremity amputations, abdominal and thoracic traumas are associated with higher rates of mortality in addition to DIC and ARDS.

Keywords: clinical features; crush syndrome; Marmara earthquake

Introduction

As compared with acute renal failure (ARF) from other causes, clinical and laboratory features of renal failure related to the crush syndrome have some unique characteristics. Because of trauma and subsequent surgical interventions, patients with crush syndrome are prone to develop bleeding, as well as wound and catheter infections, while muscle cell disintegration can result in cardiac problems, mainly because of high rates of hyperkalaemia together with hypocalcaemia [1,2]. As a result, not surprisingly, calculated mortality rates of the patients with rhabdomyolysis and/or crush syndrome who need dialysis treatment reach up to 40% or more [3–5]. On the other hand, as renal dysfunction

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is frequently the consequence of prominent volume depletion, early and aggressive fluid administration can prevent renal failure and related complications [1,6].

ARF related to the crush syndrome drew the attention of the medical community once more in the aftermath of a very catastrophic earthquake in the Marmara Region of Turkey, which occurred on 17 August 1999, at 03:01. The disaster registered 7.4 on the Richter scale, lasted for 45 s, and according to the official statistics, 17 480 deaths and 43 953 injured were reported [7], while the local estimated mortality was even higher. The seism also caused hundreds of cases of ARF on the basis of rhabdomyolysis subsequent to the crush syndrome. Detailed descriptions of epidemiology of the renal patients and offered help have been provided previously [8,9].

This study aims to analyse the clinical features of the victims who suffered from acute nephrological problems caused by this earthquake.

Subjects and methods

In order to evaluate the severity of the problem, within the first week of the disaster, the Turkish Society of Nephrology in collaboration with the Renal Disaster Relief Task Force of the International Society of Nephrology (ISN) prepared a questionnaire. The local coordinator (M.S.S.) made numerous telephone calls to the university hospitals, public hospitals, and social security hospitals located in Istanbul, Bursa, and Ankara (the potential cities, where the victims could be transferred due to logistic reasons), as well as to all university hospitals located in the western cities of Turkey, seeking the presence of any crush syndrome patients. By means of these calls, the hospitals, where crush victims were hospitalized, were identified. Of these centres, 18 were located in Istanbul, nine in Ankara, four in Bursa, and the remaining four in other cities of Turkey. The attending nephrologists, internists or doctors in charge of intensive care units were informed about the analysis and kindly asked to contribute to the study and to answer the questionnaires. This proposal was uniformly accepted and all of the centres filled in and returned the questionnaires.

The questionnaires consisted of 10 rows (each row representing one patient), and per row, 63 cells, each of which represented a clinical or a laboratory parameter. As not all the parameters were specified in the questionnaires for each variable in every patient, '*n*' figures differed. The centres were asked to return the questionnaires back only after discharging or transferring their last patient. Subsequent to the number of treated patients, the centres returned back a different number of sets, i.e. a centre where 60 patients were treated returned back six (60/10) sets of questionnaires. The hospitals that treated many patients returned the package of questionnaires by mail or courier, hospitals where only a few patients were treated simply faxed them back. As one row had to be filled in per patient, 639 rows were received; or if each row filled in per patient was considered as a 'form', 639 forms were obtained. Because of logistic or medical reasons, some patients were transferred from one reference hospital to another during the hospitalization period and, thus, two forms (or rows) were received for these particular patients. To avoid repetition in the census data, duplicated records were counted at the list of the last hospital; however, for admission data, records of the initial hospital were also taken into account. Patients with established chronic renal failure before the earthquake were excluded from the analysis. A more detailed description of this questionnaire has been provided previously [9].

Together with the questionnaires, pamphlets including treatment guidelines and also describing the indications for dialysis were distributed to the primary and secondary care centres. On the other hand, the choice of dialysis modality was made by the local physicians. According to personal communications, many medical as well as logistic variables dictated the selection for different dialysis modalities. Among the most important medical indications was the need for intensive care follow-up. These patients were more frequently treated with slow continuous therapies.

In the questionnaires, *crush syndrome* was defined as crush injury combined to systemic manifestations, such as shock, acidosis, and ARF [10]. As this analysis was restricted to renal patients, the study was confined to victims with crush syndrome and nephrological problems.

Nephrological problems were defined as crush injury and one of the following characteristics at admission: oliguria (urine output <400 ml/24 h), elevated levels of blood urea nitrogen (BUN) (>40 mg/dl), serum creatinine (>2.0 mg/dl), uric acid (>8 mg/dl), potassium (>6 meq/l), phosphorus (>8 mg/dl), or decreased serum calcium (<8 mg/dl). Victims conforming to these parameters have been the subject of this analysis. The number of the patients meeting each of the criteria to be included in the analysis has been described previously [9].

In the present study, while analysing the clinical parameters at admission (body temperature, systolic, diastolic and mean blood pressures, urinary volume), only the data of the patients who were admitted within the first 3 days of the disaster ($n=423$) were evaluated, because it was accepted that admission data of patients hospitalized later on were more related to follow-up than to the original, primary condition. Conceivably, many of the latter patients had been admitted previously to non-nephrological wards, before they were transferred to the nephrological departments of the reference hospitals. On the other hand, when other clinical parameters such as type and extent of trauma, surgical interventions for these traumatic events, clinical course, duration of oliguria and polyuria, and the clinical complications were analysed, the whole series (639 patients) was taken into account.

Statistical analysis

Descriptive statistics of all numeric variables, including means, standard deviations, minimum and maximum values, together with the proportions of all categorical variables were calculated. Medians and interquartile ranges of variables distributed non-normally, were also presented. Two independent group means were compared by means of Student's *t*-test for independent groups when the variables indicated normal distribution, otherwise Mann–Whitney *U*-test was performed. If the group variances were not homogenous as evidenced by Levene's test, *P*-values were adjusted. Differences between group proportions were examined by χ^2 test. In 2×2 contingency tables, when expected values in the cells were found to be less than 2 in any cell or less than 5 in more than half of the cells, Fisher exact test was used instead of χ^2 test. Group proportions of ordinal variables (age groups, number of extremities, etc.) were compared by Mantel–Haenzsel χ^2. Correlations between numeric variables

Table 1. Clinical admission data of the patients who were admitted within the first 3 days of the disaster ($n=423$)

Parameter	n	Mean	Median	SD	Min.	Max.
Body temperature (°C)	377	37.2	37	0.7	35.8	40
Systolic blood pressure (mmHg)	400	127	120	26	40	220
Diastolic blood pressure (mmHg)	400	77	80	15	20	140
Mean blood pressure (mmHg)	400	94	93.3	18	27	167

Values are given as mean ± SD, medians, minimums, and maximums.

Table 2. Stratified data of body temperature (A), mean blood pressure (B), and 24 h urinary volume (C) and corresponding number of the patients, admitted during the first 3 days of disaster ($n=423$)

A		B		C	
Body temperature (°C)	No. of patients	Mean BP (mmHg)	No. of patients	Urinary volume (ml/day)	No. of patients
<37	142	<59	11	0	21
37.0–37.4	115	60–89	138	5–399	206
37.5–37.9	48	90–109	183	400–999	58
38.0–38.4	46	110–129	59	1000–1999	34
⩾38.5	26	⩾130	9	⩾2000	51
$n=377$		$n=400$		$n=370$	

that distributed bi-normally, were examined by Pearson simple correlation coefficients. The correlation between all other variables and the number of traumatized extremities, the number of extremity fractures, the number of extremities with fasciotomies, and the number of amputated extremities were examined by Spearman non-parametric correlation coefficients. As numerous correlations were obtained during the statistical analysis, only the significant and clinically relevant ones are mentioned and discussed. For the analysis of the prediction of death and dialysis needs, first univariate tests (Student's t-test for independent groups for numeric variables and χ^2 test for categorical variables) were performed. Then different logistic regression models were built and possible predictors were examined. Statistical significance was assigned to P values <0.05.

Results

Taken as a whole, 9843 patients were admitted to the reference hospitals; 5302 of them were hospitalized for their treatment. Among these, 425 died (overall mortality rate 4.3%). Considering all hospitalizations, the number of patients with renal problems was 639, of which 477 (74.6%) were treated by dialysis. Accordingly, 12.0% of all hospitalized patients developed renal problems and 8.9% needed renal replacement therapy.

The demographic characteristics of these patients have been described previously [9]. To summarize, a slight dominance (54%) for the male gender was noted. Considering 620 victims in whom age was identified in the questionnaires, mean age was 31.7 ± 14.7 (range 0.3–90) years, and most (69.3%) of the victims belonged to the age strata between 10 and 40 years. The proportion of victims below the age of 10 and above 60 years was significantly lower compared with the age distribution of the general population before the earthquake [9,11].

Clinical findings at the moment of admission

Regarding admission parameters, only the data of the patients who were admitted within the first 3 days of the disaster ($n=423$) were taken into account.

The clinical findings noted at admission are summarized in Table 1. Body temperature and mean blood pressure averaged 37.2 ± 0.7°C and 94 ± 18 mmHg, respectively. Twenty-four hour urinary volume, was found to be median 218 (IQR 800) (range 0–7500) ml ($n=$ 370).

Table 2A provides body temperature data with the corresponding number of patients. Body temperature equal to or more than 37.5°C was noted in 120 of the 377 (31.8%) patients and 26 (6.9%) had fever higher than 38.5°C. Mean body temperature was higher (37.5 ± 1.0, range 35.8–40°C) in the non-survivors, compared with survivors (37.1 ± 0.7, range 36.0–39.2°C) ($P=0.027$), but did not differ significantly between the patients who were dialysed and those not dialysed.

Stratified mean blood pressure measurements and the corresponding number of patients are provided in Table 2B. Mean blood pressure at admission was higher in survivors (95 ± 17, range 47–167 mmHg) than in non-survivors (88 ± 21, range 27–147 mmHg) ($P=0.004$), and in the victims who needed dialysis support than those who were not dialysed (96 ± 18,

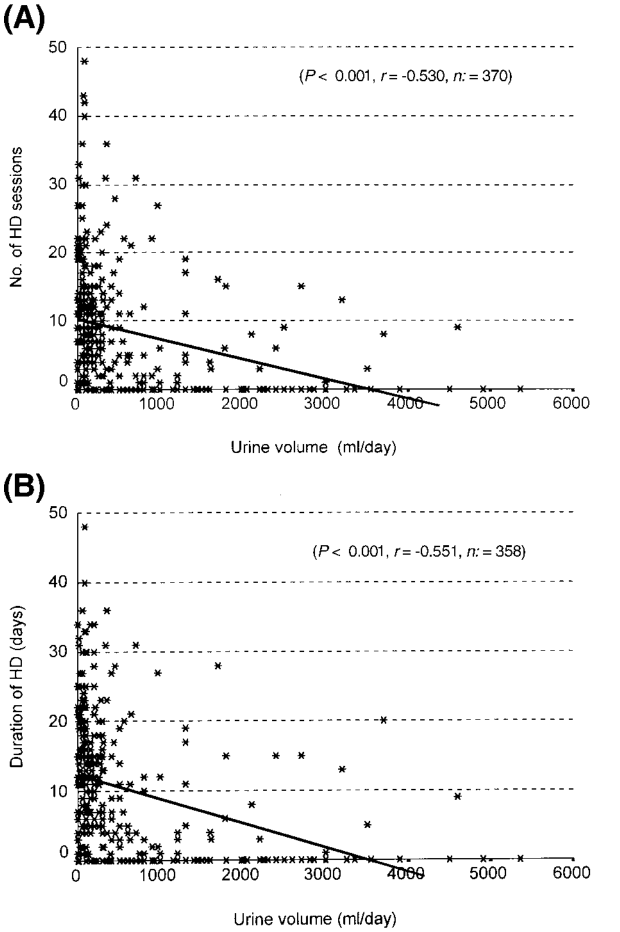

Fig. 1. Correlations between urinary volume at admission and the number of haemodialysis sessions (**A**), as well as days of haemodialysis support (**B**). HD, haemodialysis.

range 40–167 mmHg *vs* 88 ± 16, range 27–147 mmHg; $P < 0.001$).

Most of the patients were oligo-anuric at admission. Of the 370 patients whose urinary volumes were noted in the questionnaires, 227 (61.4%) had daily urinary volumes less than 400 ml, while in 51 (13.8%) urinary volumes equal to or exceeding 2000 ml/24 h were noted (Table 2C). In the non-survivors, median admission urinary volume was 140 (IQR 515) (range 0–4600) ml/day, while this parameter was 250 (IQR 845) (range 0–7500) ml/day in the survivors. Similarly, mean admission urinary volume was lower (median 150 (IQR 293) (range 0–4600) ml/day) in the dialysed patients, as compared with the victims who did not need dialysis support (median 1455 (IQR 1925) (range 0–7500) ml/day). Admission urinary volume correlated negatively with admission BUN ($P < 0.001$, $r = -0.261$, $n = 367$), serum creatinine ($P < 0.001$, $r = -0.428$, $n = 367$), phosphorus ($P < 0.001$, $r = -0.292$, $n = 205$) and potassium ($P < 0.001$, $r = -0.300$, $n = 360$), the number of blood ($P < 0.001$, $r = -0.183$, $n = 370$) and human albumin transfusions ($P < 0.001$, $r = -0.193$, $n = 370$), the number of haemodialysis sessions ($P < 0.001$, $r = -0.530$, $n = 370$) (Figure 1A), and the duration of dialysis support ($P < 0.001$, $r = -0.551$, $n = 358$) (Figure 1B).

The quantity and type of fluid administration at the disaster field could not be evidenced from this database. On the other hand, during the first admission day to the reference hospitals, the mean volume of administered fluids was 5109 ± 1711 ml. The most frequently administered solutions were isotonic saline and 5% dextrose, which were followed by mannitol and sodium bicarbonate (unpublished data).

Type and extent of trauma

The most commonly traumatized parts of the body were the extremities, of which the lower limbs were more frequently affected. In total, 790 extremity traumas were noted. There were 276 single and 160 bilateral traumas of the lower extremities. Regarding the upper limbs, 143 single and 20 bilateral injuries were reported.

The number of traumatized extremities was higher in dialysed patients (1.3 ± 0.9, range 0–4), compared with non-dialysed patients (0.9 ± 0.7, range 0–3) ($P < 0.001$), while it did not differ significantly between survivors and non-survivors. Also, the number of traumatized extremities showed positive correlations with the number of blood ($P < 0.001$, $r = 0.241$, $n = 639$), human albumin ($P = 0.006$, $r = 0.109$, $n = 639$), and fresh frozen plasma (FFP) transfusions ($P < 0.001$, $r = 0.167$, $n = 639$), while a negative correlation was noted with admission serum albumin level ($P = 0.003$, $r = -0.176$, $n = 279$).

Regarding other parts of the body, thoracic and abdominal traumas were noted in 69 and 41 cases, respectively. Mortality rates of the patients who suffered from thoracic and abdominal traumas were 31.9% (22/69) and 36.6% (15/41), respectively. Both figures were significantly higher compared with the mortality rates of the victims who did not have either thoracic ((13.2%) (75/570)) or abdominal traumas ((13.7%) (82/598)) ($P < 0.0001$ for both analyses). Most of the remaining traumas were confined to skull, columna vertebralis, or to pelvis.

Taken as a whole, 133 fractures of various bones were noted, of which 83 were restricted to the extremities.

Interestingly, considering the whole group, there were six patients who were admitted to primary care hospitals with seemingly minor traumas to the extremities and then were discharged with primary aid and dressings in a good clinical condition. Later on, these patients suffered from oliguria and other symptoms of ARF and were readmitted to the hospitals with an established ARF (Mahmut Yavuz, personal communications).

Surgical interventions

A total number of 397 fasciotomies was performed in 323 patients. The clinical course of 80 (24.8%) of these patients was complicated by sepsis, while only 41 (13.0%) of the 316 non-fasciotomized victims suffered from this complication ($P < 0.001$). Fifty-three (16.4%)

Table 3. Medical complications noted during the clinical course of crush syndrome patients with renal problems

Infectious complications	223	Pulmonary complications	83
Sepsis	121	ARDS	47
Wound infection	53	Pleural effusion	22
Pneumonia	41	Pulmonary emboli	2
Urinary tract infection	14	Pulmonary oedema	11
Other	24	Other	6
Cardiovascular complications	63	Gastrointestinal complications	23
Hypertension	32	GIS bleeding	13
Congestive heart failure	18	Gastroenteritis	5
Coronary artery disease	6	Gastroparesis	4
Pericardial complications	6	Other	4
Other	16	Neuropsychiatric complications	50
Haemotological complications	57	Peripheral neuropathy	31
DIC	44	Depression	7
Trombocytopenia	11	Paraplegia/paraparesia	4
Other	3	Other	8

The headings indicate the number of patients while the subheadings indicate the number of complications. GIS, gastrointestinal system.

and 44 (13.9%) deaths were noted amongst of the 323 fasciotomized and 316 non-fasciotomized patients, respectively ($P = 0.38$). Dialysis was performed in 271 (83.9%) fasciotomized victims, while 206 (65.2%) of the 316 non-fasciotomized patients were dialysed ($P < 0.0001$).

A total of 95 patients underwent 121 amputations, most ($n = 98$, 81.7%) of which were located at the lower extremities. Of these patients, 73, 21, and two underwent one, two, and three amputations of the extremities, respectively. Among the patients who underwent amputations, 29 (30.5%) died, whereas 68 (12.5%) deaths were noted in the remaining 544 patients ($P < 0.0001$). Presence or absence of amputations did not differ significantly in the dialysed or non-dialysed victims ($P = 0.78$).

Another common surgical procedure was the fixation of fractures, which was reported in 31 patients. Thoracic drainage was performed in 28, laparotomy in seven, peritoneal lavage in three, and other interventions in 32 patients.

In the multivariate analysis model of all traumas and surgical interventions for their impact on outcome, abdominal trauma was a strong predictor of death ($P = 0.0004$, OR = 3.75), together with thoracic trauma ($P = 0.001$, OR = 2.78).

Clinical course and medical complications

Of the 594 patients whose urinary volume was noted in the questionnaires, 424 (71.4%) had oliguria for at least 1 day. Median duration of oliguria in these patients was 10 (IQR 10), (range 1–37) days. The median oliguric period in the dialysed patients was 9 (IQR 11), (range: 0–37) days and 397 (89.8%) of these patients had oliguria for at least 1 day, while only 17.8% of the non-dialysed patients experienced 1 or more days of oliguria. Median duration of oliguria was 6 (IQR 13) days in survivors, and it was median 6 (IQR 8) days in the non-survivors. Duration of polyuria was found to be median 10 (IQR 8) (range 1–49) days. In 46 patients, urinary volumes 10 l/day were noted and this value even reached to 18 l/day in one of the victims. Overall, polyuria was noted in 87% of the dialysed victims and median polyuric period was 10 (IQR 9) days in these patients. This period was shorter (median 7 (IQR 9) days) in non-dialysed victims, 78.5% of who experienced polyuria during the clinical course. Median duration of polyuria was 10 (IQR 8) (range 0–49) days, and at least 1 day of polyuria was noted in 92.9% of the survivors, while only 41.8% of the non-survivors experienced at least 1 day of polyuria.

Medical complications apart from ARF and observed during the hospitalization period are summarized in Table 3. Considering the whole series, 329 (51.5%) of all patients suffered from at least one medical complication, either directly related or unrelated to trauma. Dialysis was required in 288 (87.5%) of the 329 patients that were complicated with medical problems, while 189 (61.0%) of the 310 patients that did not experience any medical problem needed dialysis support ($P < 0.0001$). The mortality rate was (22.5%) (74/329) in the group who suffered from medical complications superimposed to ARF, compared with 7.4% (23/310) in those whom no extra medical problems were reported ($P < 0.0001$).

The most common medical complication was infection and the most frequent infection was sepsis that was reported in 121 victims. In the univariate analysis, the mortality rate of the patients that were complicated with sepsis was higher (33/121 = 27.3%) compared with the non-septic victims (64/518 = 12.4%) ($P < 0.0001$). Also, dialysis was more frequently applied to the patients complicated with sepsis (90.1% (109/121) *vs* 71.0% (368/518)) ($P < 0.0001$).

In the multivariate analysis model of all medical complications, pneumonia ($P = 0.024$, OR = 10.35), sepsis ($P < 0.0001$, OR = 4.12), and hypertension ($P = 0.049$, OR = 5.68) were predictors of dialysis. Disseminated intravascular coagulation (DIC) ($P < 0.0001$, OR = 5.81) and adult respiratory distress syndrome (ARDS) were predictors of mortality ($P = 0.0001$, OR = 4.53).

Discussion

In this analysis, clinical features of renal victims of the catastrophic Marmara earthquake are presented. The Marmara earthquake is, to our knowledge, the disaster with the largest documented nephrological population, including 639 patients with renal problems of whom 477 needed dialysis support.

Of course, retrospective gathering of data in a multicentre study has some drawbacks, as many of the parameters considered might not have been recorded in the patient files and the methods among the centres can be heterogeneous. Other limitations are related to dramatic conditions due to the catastrophe such as shock, panic, and chaos early after the disaster and incomplete files due to victim overload. On the other hand, despite these drawbacks, it is hoped that clinical findings observed and analysed in the present study can provide helpful messages for saving lives in future massive disasters.

It is very probable that among the many possible causes of ARF, the aetiology in the present series was acute tubular necrosis due to rhabdomyolysis, at least during the admission, as these patients were presented with very high levels ($58\,205 \pm 77\,889$ IU/l) of serum creatine kinase.

The lower extremities are the most frequently traumatized parts of the body during an earthquake [3,12]. As the lower limbs include larger muscle groups, soft tissue traumas to these sections of the body may result in extensive rhabdomyolysis, and a higher incidence of ARF. In the present series, the number of the traumatized extremities was significantly higher in the dialysed patients (1.3 ± 0.9) compared with the non-dialysed ones (0.9 ± 0.7) ($P < 0.001$), confirming that the extent of extremity trauma can be taken as a predictor of nephrological problems [13].

On the other hand, we are aware of some patients who had mild injuries and were classified as minor casualties, and hence were discharged from the primary care centres early after the earthquake in good clinical condition. However, some of these patients developed oliguria and other symptoms of ARF later on, and were readmitted to the dispensaries with fully established ARF. Of course, these victims carried a high risk of fatal hyperkalaemia during the time period when they were not under the control of the health care teams. Similar observations also have been noted by other authors [3,14]. At hospital admission, performing a simple dip-stick test on the urine for haeme positivity in the mildly injured patients can diagnose subclinical rhabdomyolysis, and can hence be useful in identifying this critical condition. Therefore, all disaster victims with either mild or severe injuries should be followed-up closely for nephrological problems. If these patients are discharged because of limitation of facilities, they should be advised to check the colour and the volume of their urine daily, together with other symptoms of ARF such as weight gain, oedema, and other features. If ever such signs are noted, they should be advised to return to the hospital as soon as possible.

In the present series, 133 fractures were noted, which is discordant with the previous observations describing higher figures for fractures after the earthquakes [12,14]. This discrepancy can be explained by the fact that the present series was restricted to patients who were treated for renal problems. If a systematic injury analysis would have been performed on general hospital admission basis, the relative figure for fractures would have been higher.

Of the 639 patients, 323 (50.5%) underwent fasciotomies. This figure is very high compared with another analysis, which reports this intervention only in 13.1% of the patients with crush syndrome [3] during the Kobe earthquake. This high rate may be due to the fact that patients affected by renal problems suffer from more severe rhabdomyolysis than the global population and probably represent a more severely affected fraction of patients demography after a disaster. In the present series, fasciotomies were performed based on clinical indications, although the method for measuring intracompartmental pressure is very easy, i.e. simply to insert a regular 18-gauge needle directly into the muscle compartment and to attach this needle with an extension tube to a central venous pressure manometer, which is filled with sterile saline. In this method the extremity should be positioned approximately level with the heart and the manometer is set so that its top is level with or slightly below the compartment [15]; a pressure difference of less than 30–40 mmHg between the compartment pressure and the diastolic pressure has been suggested as an urgent indication for fasciotomy [16]. Remarkably, according to our experience, fasciotomies were found to be a significant risk factor for sepsis ($P < 0.001$), and sepsis in its turn was associated with mortality ($P < 0.0001$). Therefore, the present findings support the attitude not to undertake fasciotomies unless clear objective indications such as increased intracompartmental pressure measurements are present, because of the risk of infection related to the fasciotomy procedure [1]. The practice followed by our medical community during this disaster regarding fasciotomies was not correct and our findings contradict earlier suggestions in favour of early fasciotomy [14,16].

Medical treatment of the compartmental syndrome by mannitol has been proposed as an effective and less hazardous alternative to surgical intervention [17]. As mannitol administration is also indicated for the prevention of ARF, this approach may improve the final outcome of the victims through several mechanisms.

Of the 377 patients whose admission body temperature was reported in the questionnaires, 120 (31.8%) were noted to have body temperatures equal to or above 37.5°C and this parameter was significantly higher in the non-survivors. Rhabdomyolysis by itself may cause fever [18]; hence it is reasonable to think that at least in some of the patients fever was a consequence of the trauma. On the other hand, the most frequent cause of fever, i.e. the infections, either in systemic or localized (wound) forms might also have been responsible for this finding. As infection, especially sepsis, was a risk factor for death ($P < 0.0001$), higher mortality rates in patients with high fever may also be related to these infectious complications.

In the present series, surprisingly, patients with a higher mean blood pressure at admission more frequently required dialysis. We can only speculate about the reasons for this unexpected finding. Perhaps, blood pressure rises might have been the consequence of renal functional disturbances and/or the subsequent fluid overload.

Most of the victims were oligo-anuric at admission, which may be related to volume deficits. According to the initial observations, it was clear that some of the ARF-patients were severely dehydrated. This was an expected finding for several reasons: (i) the chaotic conditions of extrication and transport; (ii) the outside temperatures, up to 38°C in the shade, with most of the local hospitals destroyed, so that patients were treated in open air and in the sun; (iii) sequestration of many litres of extracellular volume in severely damaged muscles [8].

As generous replenishment of fluids is of vital importance in the treatment of these victims, within the first days of the disaster ISN-RDTF and the Turkish Society of Nephrology developed various strategies to pursue early rehydration. First, the general practitioners on the field were briefed about the characteristics of the crush syndrome, and about the appropriate fluid administration as well as treatment of hyperkalemia. Then, they were asked to transmit this information to the local primary care doctors, responsible for triage and first aid [8]. On the other hand, despite these efforts, dehydration should take a place in the pathogenesis of oliguria, at least in some of these victims. Unexpectedly, in 51 patients, urinary volumes equal to or above 2000 ml/24 h were noted. This may be related to the polyuric phase of acute tubular necrosis or previous administration of large volumes of fluids in the primary health care centres.

In the present series, mean age of the renal victims was quite young (31.7 ± 14.7), which can have had a favourable effect on prognosis, while still other variables are needed to estimate the ultimate outcome. Mortality and need for dialysis support were more frequent in the patients with medical complications. This is not surprising, as more heavily traumatized victims carry a higher risk of medical complications, such as infections, DIC, and fluid–electrolyte imbalance. Sepsis was the most frequent medical complication, which was significantly correlated with mortality ($P < 0.0001$); and in the multivariate analysis, significant risk factors for mortality were ARDS and DIC; the latter can by itself be a complication of rhabdomyolysis and/or sepsis [19]. Estimating renal outcome in advance can be important for planning the logistics. Besides the clinical and laboratory findings, other means such as Doppler ultrasound of the kidneys can be helpful for assessing the prognosis in this patient population [20].

To conclude, during the catastrophic earthquakes, clinical findings of the renal victims are of vital importance since they can predict the final outcome as well as be directive for medical therapies and logistic interventions in the future. In the case of complications such as ARDS and DIC, both of which are strong predictors of mortality, the patients should be transferred to an intensive care unit at the earliest occasion for close follow-up. The early detection of life-threatening signs, may give the opportunity to start immediate therapy, thus improving the prognosis of the patients. However, one should note that the transportation of these patients over considerable distances can also lead to increased morbidity and mortality and, therefore, the risk to the patient of transport needs should be balanced against the benefits of treating them in an intensive care unit, which indicates that the decision about transportation should be individualized.

References

1. Better OS. The crush syndrome revisited (1940–1990). *Nephron* 1990; 55: 97–103
2. Vanholder R, Sever MS, Erek E, Lameire N. Rhabdomyolysis. *J Am Soc Nephrol* 2000; 11: 1553–1561
3. Oda J, Tanaka H, Yoshioka T *et al*. Analysis of 372 patients with crush syndrome caused by the Hanshin-Awaji earthquake. *J Trauma* 1997; 42: 470–476
4. Ward MM. Factors predictive of acute renal failure in rhabdomyolysis. *Arch Intern Med* 1988; 148: 1553–1557
5. 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
6. Shimazu T, Yoshioka T, Nakata Y *et al*. Fluid resuscitation and systemic complications in crush syndrome: Hanshin-Awaji earthquake patients. *J Trauma* 1997; 42: 641–646
7. T.C. Basbakanlik Kriz Yonetim Merkezi. Depremler 1999. Basbakanlik Basimevi, Ankara, 2000; s3–s15 (Crisis Center of the Turkish Prime Ministry. Earthquakes 1999, Press of Prime Ministry, Ankara, 2000; 3–15)
8. Vanholder R, Sever MS, De Smet M, Erek E, Lameire N. The intervention of the Renal Disaster Relief Task Force in the North-West Turkey Marmara earthquake. *Kidney Int* 2001; 59: 783–791
9. Sever MS, Erek E, Vanholder RV *et al*. The Marmara earthquake—epidemiological analysis of the victims with nephrological problem. *Kidney Int* 2001; 60: 1114–1123
10. Slater MS, Mullins RJ. Rhabdomyolysis and myoglobinuric renal failure in trauma and surgical patients: a review. *J Am Coll Surg* 1998; 186: 693–716
11. Reports of Statistics Institution of Turkish Prime Ministry, 1997
12. Peek-Asa C, Kraus JF, Bourque LB, Vimalachandra D, Yu J, Abrams J. Fatal and hospitalized injuries resulting from the 1994 Northridge earthquake. *Int J Epidemiol* 1998; 27: 459–465
13. Tattersall JE, Richards NT, McCann M, Mathias T, Samson A, Johnson A. Acute haemodialysis during the Armenian earthquake disaster. *Injury* 1990; 21: 25–28
14. Zhi-Yong S. Medical support in Tangshan earthquake: a review of the management of mass casualties and certain major injuries. *J Trauma* 1987; 27: 1130–1136

15. Perry MO. Compartment syndromes and reperfusion injury. *Surg Clin North Am* 1988; 68: 853–864
16. Shaw AD, Sjolin SU, McQueen MM. Crush syndrome following unconsciousness. Need for urgent orthopedic referral. *Br Med J* 1994; 309: 857–859
17. Better OS, Rubinstein I, Winaver JM, Knochel JP. Mannitol therapy revisited (1940–1997). *Kidney Int* 1997; 52: 886–894
18. Knochel JP. Rhabdomyolysis and acute renal failure. In: Glassock RJ, ed. *Current Therapy in Nephrology and Hypertension*, 4th edn. Mosby, St Louis, MO, 1998; 262–265
19. Honda N. Acute renal failure and rhabdomyolysis. *Kidney Int* 1983; 23: 888–898
20. Keven K, Ates K, Yagmurlu B *et al*. Renal Doppler ultrasonographic findings in earthquake victims with crush injury. *J Ultrasound Med* 2001; 20: 675–679

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