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The Marmara earthquake: admission laboratory features of patients with nephrological problems

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Abstract

Background. Earthquakes are major causes of morbidity and mortality. North-western Turkey was struck by a devastating earthquake in August 1999, which caused several thousand deaths. Among the most important morbid events in survivors were acute nephrological problems.

Methods. Within the first week of the disaster, specific questionnaires asking about 63 clinical and laboratory parameters were sent to 35 reference hospitals that were treating the victims. Of the registered 639 victims, 423 were admitted within the first 3 days of the disaster; the admission laboratory data of these 423 patients are the subject of this analysis.

Results. In the 423 patients (233 males, mean age 31.3 ± 14.4 years), time under the rubble was 10.7 ± 10.4 h. Mean values at admission were as follows: serum potassium 5.4 ± 1.3 mEq/l, creatine phosphokinase $58\,205 \pm 77\,889$ IU/l, albumin 2.6 ± 0.7 g/dl, phosphorus 5.2 ± 1.8 mg/dl, haematocrit $35.0 \pm 9.3\%$, leukocyte count $14\,945 \pm 6614/\text{mm}^3$, platelet count $1\,83\,975 \pm 1\,34\,012/\text{mm}^3$, blood urea nitrogen 55.1 ± 28.9 mg/dl, and creatinine 3.9 ± 2.3 mg/dl. Serum potassium above 6.5 mEq/l was noted in 91 patients (22.7%), an alarming finding for risk of fatal arrhythmias. Non-survivors were characterized by higher figures of serum potassium ($P = 0.001$), as well as lower haematocrit ($P = 0.028$), platelets ($P < 0.001$), and serum albumin ($P = 0.003$). In a multivariate analysis model of admission laboratory parameters, serum creatinine ($P < 0.001$, $o.r. = 2.19$), potassium ($P = 0.001$, $o.r. = 3.64$), and phosphorus ($P = 0.004$, $o.r. = 1.78$) predicted dialysis needs, whereas serum albumin ($P = 0.028$, $o.r. = 0.23$) and creatinine ($P = 0.039$, $o.r. = 0.60$) were related to mortality.

Conclusions. Admission laboratory data may be useful for predicting dialysis needs and survival chance of disaster victims. High incidences of some life-threatening abnormalities dictate the need for empirical therapy even in the field.

Keywords: acute renal failure; crush syndrome; dialysis; hyperkalaemia; laboratory findings; Marmara earthquake

Introduction

Acute renal failure (ARF) is a frequent complication of rhabdomyolysis, which is frequently encountered in conjunction with natural catastrophes. These renal problems have been claimed to carry unique laboratory features as compared to other causes of ARF such as increased serum levels of muscle enzymes and a higher ratio of creatinine/blood urea nitrogen (BUN), as well as higher degrees of uricaemia, phosphataemia and, most importantly, life-threatening hyperkalaemia [1]. When these laboratory abnormalities come together with a high incidence of surgical and medical complications [2], calculated mortality rates of up to 40% in dialysed patients can be expected [3–5].

Turkish nephrologists were faced with all these problems in August 1999 following a devastating earthquake which registered 7.4 on the Richter scale,

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and which struck the north-western part of the country. It resulted in 17 480 deaths and 43 953 injured according to the official statistics [6]; locally estimated mortality was even higher. The disaster also caused serious renal problems in many victims, directly contributing to trauma-related morbidity and mortality. Detailed descriptions of the disaster, including offers of help as well as epidemiological features of the renal patients, have been provided in other publications [7,8].

The present analysis concentrates on the admission biochemical data obtained of the victims who suffered from acute nephrological problems caused by this earthquake. By analysing this data, we aimed to search for the variables that influence morbidity and mortality, and which therefore might be helpful in planning interventions in the case of future disasters.

Patients and methods

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 questionnaires to analyse the extent of the nephrological problems. These questionnaires were sent to nephrology units of 35 reference hospitals that were treating the victims. Reference hospitals were defined as secondary- or tertiary-care centres that had a sufficient number of critical-care beds with advanced equipment such as dialysis and intensive-care units, and that had experienced medical and surgical teams. A detailed outline of the questionnaire has been described previously [8]. In brief, it consisted of five pages asking about 63 variables considering the demographics, clinical and laboratory findings, therapeutic modalities, and the final outcomes of the crush injured victims with nephrological problems.

In the questionnaires, *crush syndrome* was defined as crush injury and systemic manifestations such as shock, acidosis, and ARF [9]. The term *nephrological problem* was defined as at least one of the following criteria at admission: oliguria (urinary output <400 ml/day), elevated levels of BUN (>40 mg/dl), serum creatinine (SCr) (>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) in patients with crush syndrome. For hypoalbuminaemic victims, serum calcium levels were corrected. *Corrected calcium* values were calculated by an increase of 0.8 mg/dl of the measured serum calcium, for each 1.0 g/dl fall in the plasma albumin concentration beyond the normal levels of 3.5–5.0 g/dl [10]. The number of patients meeting the criteria to be included in the analysis has been described elsewhere [8].

Such a broad definition of nephrological problems, which considered more than SCr, urea, and urinary volume alone, was dictated by our concern to include all victims whose kidneys could not cope with the metabolic derangements of crush injury at that particular time.

Together with the questionnaire, pamphlets, including treatment guidelines (which also described the indications for dialysis), were distributed to the primary and secondary care centres. According to these guidelines, the indications for dialysis were: BUN >100 mg/dl, serum potassium >7 mEq/l, creatinine >8 mg/dl, blood pH <7.1, bicarbonate <10 mEq/l, and/or any clinical symptoms related to uraemia. More liberal indications or even prophylactic dialyses were applied in exceptional (mostly hypercatabolic) cases if this was considered necessary, e.g. when potassium rose very rapidly, even in the absence of hyperkalaemia [11]. All these indications were defined by the local physicians.

Of the registered 639 victims, 423 were admitted within the first 3 days of the disaster, and their admission laboratory data is the subject of this analysis. In the present study, raw and stratified data, statistical comparisons, and correlations will be provided about serum potassium, creatine phosphokinase (CK), albumin, creatinine, BUN, and blood-count parameters, since they are the main vital parameters related to renal function, muscular damage, and inflammatory and nutritional status. Considering other parameters (serum uric acid, calcium, phosphorus, alanine aminotransferase, aspartate aminotransferase, and lactic dehydrogenase), which are more indirectly related to outcome, only raw data will be given because of space limitations. Detailed analyses, statistics, and discussion of the latter will be the subject of a separate study.

Statistical analysis

Descriptive statistics of all numeric variables including means, standard deviations, and minimum and maximum values, together with the proportions of all categorical variables were calculated. Two independent group means were compared by means of Student's t test for independent groups. If the group variances were not homogeneous as evidenced by Levene's test, P values were adjusted.

Admission laboratory findings were correlated with individual characteristics of the victims (age, time spent under the rubble, lapse between disaster and date of admission to reference hospitals), with clinical findings at admission and hospitalization (24-h urinary volume, mean blood pressure, body temperature, number of traumatized extremities, and duration of oliguria and polyuria), and with therapeutic interventions (numbers of fasciotomized and amputated extremities; blood, fresh frozen plasma (FFP), and human albumin transfusions; haemodialysis sessions, and days for haemodialysis support). Correlations between numeric variables 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. P values were not adjusted when multiple statistical tests were performed.

For the prediction of death and dialysis needs, univariate tests (Student's t test for independent groups for numeric variables) were performed first. Then logistic regression analysis was performed. Admission laboratory parameters (which included blood count, BUN, SCr, uric acid, potassium, corrected calcium, phosphorus, and albumin) were defined as predictors, all in one block (all as numeric variables). To select significant predictors, a forward selection method was used with entry cut-off value for a P value of 0.05 and a removal cut-off value for a P value of 0.10. Statistical significance was assigned to P values less than 0.05.

Results

General features

Taken as a whole, 9843 patients were admitted to the reference hospitals; 5302 of them were hospitalized and 425 died (an overall mortality rate of 4.3%). Considering all hospitalizations, the number of patients with renal problems was 639 (12.0%) of whom 477 (8.9%) were treated by dialysis. To summarize the demography, there was a slight dominance for the male gender (male/female, 348/291) and the mean overall age was 31.7 ± 14.7 years. The proportions of victims below the age of 10 and above 60 were significantly lower compared to the age distribution of the general population in the corresponding area, at the time of earthquake [8].

Overall, the most commonly traumatized parts of the body were the extremities, 790 extremity traumas being noted. 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 significantly higher compared to the cases not complicated by these traumas (unpublished data).

Of the 603 victims whose admission data were specified in the questionnaires, 423 (70.1%) were admitted to reference hospitals within the first 3 days of the disaster, and hence became the subject of this analysis.

To summarize the clinical findings in the early-admitted victims at the time of admission, 61.4% were characterized by oliguria, 31.8% by high fever, and 35% by a mean blood pressure lower than 90 mmHg. Non-survivors were admitted with higher body temperature, lower mean blood pressure and lower urinary volume, while dialysed victims were characterized by higher mean blood pressure and lower urinary volume (unpublished data).

Mean age (31.3 ± 14.4 years) and gender distribution (233 male, 190 female) of these early-admitted victims were not significantly different from those victims who were admitted later; however, in this particular group, the time spent under rubble was shorter (10.7 ± 10.4 *vs* 14.5 ± 21.0 h, $P = 0.03$). In addition, the mortality rate of these first-admitted patients was higher than those who were admitted later (17.7% (75/423) *vs* 10.0% (18/180), $P = 0.016$). On the other hand, there was no significant difference between the two groups for dialysis needs.

Biochemical parameters at the time of admission

Table 1 provides the means, standard deviations, and ranges of the admission laboratory parameters. Mean serum potassium at admission was 5.4 ± 1.3 (range 2.4–13.3) mEq/l, and 91 (22.7%) patients were admitted with serum potassium levels above 6.5 mEq/l. The number of patients corresponding to various strata of serum potassium at the time of admission is provided in Figure 1. Serum potassium level was higher in the victims who needed dialysis support (5.7 ± 1.3, range 2.4–13.3 mEq/l *vs* 4.7 ± 0.9, range 2.7 ± 8.9 mEq/l, $P < 0.001$) and in the non-survivors (6.0 ± 1.7, range 3–13.3 mEq/l *vs* 5.3 ± 1.2, range 2.4–8.4 mEq/l, $P = 0.001$). Potassium levels correlated negatively with 24-h urine volume at admission ($P < 0.001$, $r = -0.251$, $n = 360$), and positively with CK ($P < 0.001$, $r = 0.432$, $n = 69$), the number of traumatized extremities ($P = 0.004$, $r = 0.142$, $n = 401$), fasciotomized extremities ($P < 0.001$, $r = 0.173$, $n = 401$), blood transfusions ($P = 0.026$, $r = 0.111$, $n = 401$), human albumin transfusions ($P < 0.001$, $r = 0.201$, $n = 401$), number of haemodialysis sessions ($P < 0.001$, $r = 0.243$, $n = 401$), and days of haemodialysis support ($P < 0.001$, $r = 0.236$, $n = 395$).

Mean serum level of CK at admission was 58 205 ± 77 889 IU/l and it was higher in patients requiring dialysis (66 713 ± 83 456, range 77–459 800 IU/l) *vs* non-dialysed patients (20 901 ± 22 999, range 1384–85 652 IU/l) ($P = 0.018$). However, this parameter did not show significant differences between survivors and non-survivors. Stratified serum CK levels and corresponding number of patients are provided in

Table 1. Initial biochemical laboratory data in the patients admitted within the first 3 days of the disaster ($n = 423$)*

Parameter	*n*	Mean	SD	Min	Max
Potassium (mEq/l)	401	5.4	1.3	2.4	13.3
CK (U/l)	70	58 205	77 889	77	459 800
Albumin (g/dl)	279	2.6	0.7	1.1	4.8
Hct (%)	400	35.0	9.3	9.1	63.6
Leukocytes (/mm^3)	373	14 945	6614	3000	50 100
Platelets (/mm^3)	367	183 975	134 012	8600	2 130 000
BUN (mg/dl)	411	55.1	28.9	9	269
Creatinine (mg/dl)	409	3.9	2.3	0.3	16.1
Uric acid (mg/dl)	241	6.5	2.5	1.3	17.9
Calcium (mg/dl)	265	7.8	1.0	6	11.8
Corr. calcium (mg/dl)	221	8.8	0.9	6.9	12.4
Phosphorus (mg/dl)	218	5.2	1.8	0.7	12.4
AST (U/l)	143	859	1050	2	9245
ALT (U/l)	141	826	5374	8	64 000
LDH (U/l)	72	2762	2874	182	18 940

*Values are given as means ± standard deviations, minima, and maxima. Since not all parameters were specified in all questionnaires, '*n*' figures are variable. Min, minimum; Max, maximum; SD, standard deviation; CK, creatine phosphokinase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; LDH, lactic dehydrogenase; Corr. calcium, serum calcium corrected for serum albumin.

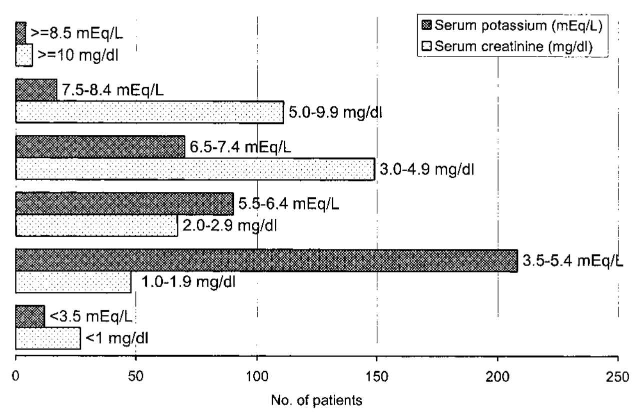

Fig. 1. Number of patients corresponding to various strata of serum potassium ($n = 401$) and creatinine ($n = 409$) at the time of admission.

Table 2A. This parameter correlated negatively with the time lapse between the disaster and the hospital admission ($P = 0.003$, $r = -0.356$, $n = 70$) and positively with the number of fasciotomized extremities ($P = 0.019$, $r = 0.279$, $n = 70$), as well as human albumin transfusions ($P < 0.001$, $r = 0.510$, $n = 70$).

Hypoalbuminaemia was a common finding at admission, since 195 (69.9%) of the 279 victims whose serum albumin was specified in the questionnaires presented with serum albumin levels lower than 3 g/dl (Table 2B). Admission serum albumin level was significantly lower in the victims who needed dialysis (2.5 ± 0.7, range 1.3–4.8 g/dl *vs* 2.7 ± 0.7, range: 1.1–4.2 g/dl, $P = 0.036$). Also, lower levels of serum albumin were noted in non-survivors (2.3 ± 0.7, range 1.3–4.8 g/dl) as compared to survivors (2.6 ± 0.7, range 1.1–4.4 g/dl), ($P = 0.003$). Serum albumin correlated negatively with the time period under the rubble ($P = 0.002$, $r = -0.199$, $n = 233$), admission body temperature ($P < 0.001$, $r = -0.198$, $n = 259$), serum phosphorus ($P = 0.028$, $r = -0.161$, $n = 186$), number of blood transfusions ($P < 0.001$, $r = -0.228$, $n = 279$), FFP transfusions ($P < 0.001$, $r = -0.217$, $n = 279$) and human albumin transfusions ($P < 0.001$, $r = -0.245$, $n = 279$), and the number of haemodialysis sessions ($P = 0.030$, $r = -0.130$, $n = 279$).

Of the 400 patients whose haematocrit values were recorded in the questionnaires, 116 (29%) and 25 (6.3%) were admitted with haematocrit levels lower than 30% and equal to or above 50% respectively. Stratified data for admission haematocrit and corresponding numbers of patients are shown in Table 2C.

Considering dialysis needs and final outcome of the patients, leukocyte count was higher ($P = 0.002$) and platelet count was lower ($P = 0.006$) in the dialysed victims, while haematocrit ($P = 0.028$) and platelets ($P < 0.001$) were lower in the non-survivors (Table 3).

Haematocrit and white blood cell and platelet counts at admission correlated with many clinical and laboratory findings, amongst which the most relevant ones were: haematocrit correlated positively with admission leukocytes ($P < 0.001$, $r = 0.455$, $n = 367$), platelets ($P = 0.027$, $r = 0.116$, $n = 365$), serum albumin ($P = 0.002$, $r = 0.191$, $n = 273$), and negatively with the time lapse between the disaster and admission to the reference hospitals ($P = 0.024$, $r = -0.113$, $n = 400$), as well as with the number of blood transfusions ($P < 0.001$, $r = -0.175$, $n = 400$) and FFP transfusions ($P = 0.002$, $r = -0.158$, $n = 400$). Considering leukocyte counts, positive correlations with platelets ($P < 0.001$, $r = 0.220$, $n = 367$), serum potassium ($P < 0.001$, $r = 0.213$, $n = 366$), and negative correlations with the

Table 2. (A) Stratified serum creatine phosphokinase, (B) albumin, (C) haematocrit, and (D) BUN levels and corresponding numbers of patients at the time of admission*

Serum CK (U/l)	Patients (*n*)	Serum alb. (g/dl)	Patients (*n*)	Hct (%)	Patients (*n*)	BUN (mg/dl)	Patients (*n*)
< 1000	4	< 1.5	11	< 20	18	< 20	24
1000–9999	18	1.5–1.9	39	20–29.9	98	20–39	98
10 000–49 999	21	2.0–2.9	145	30.0–39.9	168	40–69	201
50 000–99 999	14	3.0–3.4	49	40.0–44.9	62	70–99	64
100 000–249 000	10	3.5–4.4	34	45–49.9	29	100–199	22
⩾250 000	3	⩾4.5	1	⩾50	25	⩾200	2
n = 70		*n* = 279		*n* = 400		*n* = 411	
A		B		C		D	

*Patients (*n*), number of patients; CK, creatine phosphokinase; alb., albumin; Hct, haematocrit; BUN, blood urea nitrogen.

Table 3. Admission haematocrit and leukocyte and platelet counts in the patients who did and did not need dialysis support, as well as those who survived or died later*

Parameter	Status of the victims	Mean	SD	Min	Max	*P*
Haematocrit (%)	Non-dialysed (*n* = 108)	35.2	7.4	13.3	52.1	= 0.466
	Dialysed (*n* = 292)	34.9	9.9	9.1	63.6	
	Survivors (*n* = 330	35.5	9.1	13.3	63.6	= 0.028
	Non-survivors (*n* = 70)	32.3	9.8	9.1	54.3	
Leukocytes (/mm^3)	Non-dialysed (*n* = 91)	13 227	5692	4900	34 600	= 0.002
	Dialysed (*n* = 282)	15 499	6803	3000	50 100	
	Survivors (*n* = 308)	14 909	6480	3000	50 100	= 0.979
	Non-survivors (*n* = 65)	15 111	7268	4300	38 100	
Platelets (/mm^3)	Non-dialysed (*n* = 90)	194 596	91 858	8600	653 000	= 0.006
	Dialysed (*n* = 277)	180 525	145 072	14 500	2 130 000	
	Survivors (*n* = 303)	192 557	141 398	8600	2 130 000	< 0.001
	Non-survivors (*n* = 64)	143 344	80 383	26 000	428 000	

*Min, minimum; Max, maximum; SD, standard deviation.

age of the victims ($P=0.036$, $r=-0.110$, $n=364$), as well as admission urinary volume ($P=0.004$, $r=-0.157$, $n=338$) were noted. Platelet counts correlated positively with the time spent under the rubble ($P<0.001$, $r=0.218$, $n=308$) and the number of FFP transfusions ($P=0.019$, $r=0.123$, $n=367$).

Mean BUN level was 55.1 ± 28.9 (range 9–269) mg/dl at admission. Almost half of the patients were admitted with BUN levels between 40 and 70 mg/dl (Table 2D). This parameter was higher in the dialysed (58.6 ± 28.8, range 13–269 mg/dl) *vs* non-dialysed victims (45.4 ± 26.9, range 9–149 mg/dl, $P<0.001$); no significant difference was observed between survivors and non-survivors. BUN levels correlated negatively with 24-h urinary volume at admission ($P<0.001$, $r=-0.207$, $n=367$) and positively with the time lapse between the disaster and the moment of admission to the reference hospitals ($P=0.001$, $r=0.161$, $n=411$), SCr ($P<0.001$, $r=0.540$, $n=407$), uric acid ($P<0.001$, $r=0.233$, $n=240$), potassium ($P<0.001$, $r=0.204$, $n=400$), and albumin ($P=0.038$, $r=0.124$, $n=278$), while borderline level of significance was observed with mean arterial blood pressure ($P=0.051$, $r=0.098$, $n=394$).

Mean SCr concentrations was equal to or more than 2.0 mg/dl in 334 (81.7%) of the 409 victims (Figure 1). This parameter was higher in the patients who were started on dialysis later during their evolution (4.6 ± 2.2, range 0.5–16.1 mg/dl *vs* 2.3 ± 1.5, range 0.3–7.8 mg/dl, $P<0.001$); however, no significant difference was noted between survivors and non-survivors. Admission SCr correlated negatively with the time period under the rubble ($P=0.003$, $r=-0.159$, $n=339$) and urinary volume ($P<0.001$, $r=-0.313$, $n=367$), while positive correlations were noted between serum potassium ($P=0.001$, $r=0.168$, $n=400$), phosphorus ($P=0.002$, $r=0.206$, $n=217$), days of oliguria ($P<0.001$, $r=0.308$, $n=379$), the number of haemodialysis sessions ($P<0.001$, $r=0.277$, $n=409$), and days on haemodialysis support ($P<0.001$, $r=0.356$, $n=395$) (Figures 2 and 3).

In the multivariate analysis model of admission laboratory parameters, SCr ($P<0.001$, *o.r.* $=2.19$), potassium ($P=0.001$, *o.r.* $=3.64$), and phosphorus ($P=0.004$, *o.r.* $=1.78$) were found to be predictors of dialysis needs. Serum albumin ($P=0.028$, *o.r.* $=0.23$)

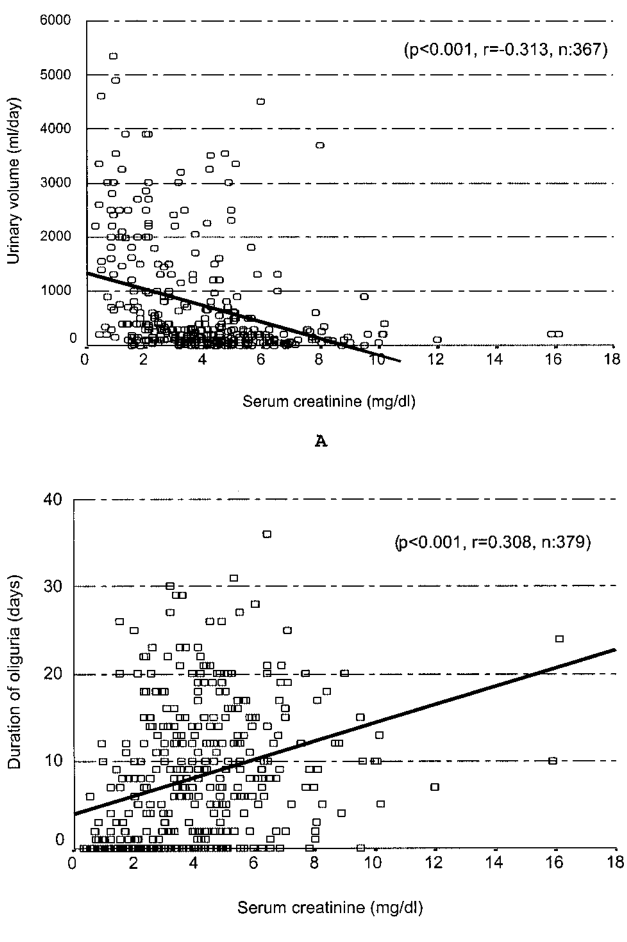

Fig. 2. Correlations between (A) admission SCr and urinary volume (UV) and (B) duration of oliguria (DO). (UV = 1325–151 SCr), (DO = 3.955 + 1.047 SCr).

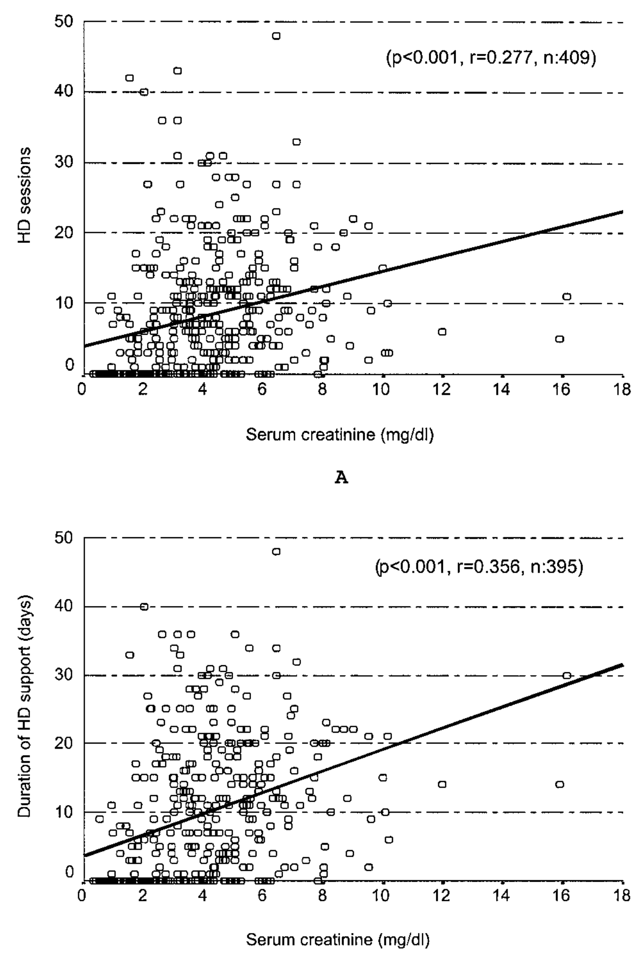

Fig. 3. Correlations between (A) admission SCr and number of haemodialysis sessions (*n*HD) and (B) duration of haemodialysis support (DHD). (*n*HD = 3.891 + 1.071 SCr), (DHD = 3.660 + 1.550 SCr.)

and creatinine ($P = 0.039$, $o.r. = 0.60$) were related to mortality in this analysis.

Discussion

Admission laboratory findings of disaster victims are of vital importance, since many of them are hospitalized with life-threatening biochemical abnormalities and initial therapeutic interventions are based on this data.

In the present series, admission laboratory parameters of the victims who were admitted within the first 3 days of the disaster were analysed with the concern that laboratory parameters (especially the muscle enzymes) might have changed by time, as there were patients admitted to reference hospitals up to 1 month after the disaster. However, it should be stressed that even these results may not represent the exact laboratory profile of a disaster victim who has been just extricated from the rubble, since time lapse between disaster and admission to hospitals can blur the findings and even hours can have an impact on blood test results.

It has been reported that many victims experience dangerous hyperkalaemia at the disaster field [12]. Cardiotoxicity of hyperkalaemia is aggravated by hypocalcaemia, another laboratory abnormality that is also frequently noted in the crush syndrome [1]. Therefore, many casualties with extreme hyperkalaemia might have not been analysed due to pre-hospital fatality, and early prevention and treatment of this complication in the disaster field can save many lives. Data of the present series also support the rationale for initiating empirical therapy for hyperkalaemia with potassium exchange resins even before hyperkalaemia is detected, as has been suggested previously [12,13].

A rise of serum muscle enzymes, especially CK, is the most prominent and earliest laboratory feature of muscle injury. Different threshold values, from 500 to 3000 U/l, have been proposed as indicators of rhabdomyolysis [2,4,14]. Peak values are recorded immediately at admission or within the first 24 h after hospitalization [3,4]. Low values noted in this series may be the result of a steady decrease of serum levels of the enzyme by time.

As can be noted, the number of CK measurements provided in the present analysis was quite low compared to other parameters. The most important reason of this low figure is that only the records of university hospitals were taken into account for statistics, since in many public hospitals serum dilutions were not made during the analysis of serum CK, because of a heavy workload in the aftermath of the disaster.

Both high and low values of admission serum albumin can be expected during disasters. While dehydration at an early stage results in hyperalbuminaemia; malnutrition, inflammation, capillary leak, and fluid overload may cause hypoalbuminaemia at a later stage [11]. Opinions about the prognostic value of serum albumin levels at admission are controversial. Hyperalbuminaemia may be an ominous sign [14], because it indicates haemoconcentration and severe dehydration; on the other hand, since hypoalbuminaemia is related to a low serum α_2-globulin, the carrier protein of myoglobin, a decrease of α_2-globulin may result in a decreased binding of myoglobin, and hence increased nephrotoxicity [4].

In the present series, low serum albumin reflects a poor prognosis. Hypoalbuminaemia has previously been noted to be a risk factor of mortality in ARF of different aetiologies [15].

In the present series, 29% of the patients had haematocrits lower than 30%, while only 6.2% presented with levels higher than 50%. Low values of haematocrit may indicate either blood loss or haemodilution in the oligoanuric patients if they received large amounts of fluids. The latter mechanism may be a significant contributing factor, since from the second day of the disaster on, pamphlets of the ISN and the Turkish Society of Nephrology were provided to primary-care physicians advising early and energetic volume substitution [7]. In addition, the negative correlation between haematocrit and the time lapse between the disaster and admission may suggest that the patients who were admitted later had received more fluids. On the other hand, haematocrit values higher than 50% may indicate severe dehydration, as has been suggested previously [4,16]. The correlation between haematocrit and serum albumin may also indicate that these two parameters evolved in parallel, as well in dehydrated as in overhydrated states, and further corroborates the above-mentioned suggestion.

In the present series the majority of patients presented with leukocytosis, which might have been the result of rhabdomyolysis *per se* [13,17] or of accompanying infectious complications. Lower platelet counts were more frequently noted in the non-survivors and dialysed victims; this finding may point to disseminated intravascular coagulation (DIC), which is a possible complication of sepsis and rhabdomyolysis [13,18]. On the other hand, thrombocytopenia without DIC has also been reported in conjunction with rhabdomyolysis [18]. The negative correlation between serum CK levels and platelet count may also point to such a relationship.

The majority of the patients were admitted with elevated levels of BUN and SCr. A higher ratio of SCr/BUN has been suggested in patients with rhabdomyolysis, possibly because of the release of creatinine from damaged muscle cells [1,18,19]; nevertheless, not all authors confirm this hypothesis [14,20]. In the present series the ratio of SCr/BUN was 1/14.1 (3.9/55.1), which fits into the presumed physiological ratio of 1/10–15 [10]. Therefore the possibility should be considered that creatinine generation is not increased in rhabdomyolysis. Alternatively, we suggest that in addition to a high production of creatinine, increased urea generation by the liver in these seriously traumatized and highly catabolic patients [10] may contribute to the maintenance of this physiological ratio.

These traumatized, surgical victims who are also (usually) poorly nourished in disaster conditions, represent typical hypercatabolic patients. Hypercatabolism is characterized by abnormal protein breakdown; therefore, by itself it contributes to the complications of rhabdomyolysis, especially hyperkalaemia as well as hyperphosphataemia, metabolic acidosis, and higher levels of nitrogenous waste products. In the present series, most of these features were characterized by higher needs of dialysis and mortality, underlying the importance of very close follow-up in disaster victims, and treatment of the complications as soon as possible; such a policy should be effective in preventing the metabolic consequences of hypercatabolism, and thus improving the final outcome.

To conclude, the Marmara earthquake was one of the most devastating disasters of this century and our experience covered one of the largest databases of simultaneous crush victims in disaster conditions. Since many victims were admitted to reference hospitals with potentially fatal hyperkalaemia, the first concern should be to treat or prevent this complication. The victims with hyperkalaemia, hyperphosphataemia, and high admission SCr are candidates for higher needs of dialysis, while non-survivors were characterized by hypoalbuminaemia and elevated SCr; therefore these patients should be followed up more closely. From the technical point of view, although rare, it was noted that some of the victims transferred from the disaster field received solutions containing potassium; therefore education of the primary care physicians for the treatment of crush syndrome is of vital importance. It is hoped that these data may be helpful in planning interventions in the case of any future disasters.

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