ORIGINAL ARTICLE

Crush syndrome patients after the Marmara earthquake

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Background: To assess the treatment and outcome of patients with crush injury sustained in the Marmara earthquake.

Methods: Seven hundred eighty three patients were transferred to a university hospital and 25 of them were admitted to the intensive care unit. The medical records of 18 crush injury patients were retrospectively reviewed.

Results: The major associated injuries were in the lower extremities, upper extremities, and chest. Seven patients underwent fasciotomy and six patients had amputations. Twelve patients required mechanical ventilation. Adult respiratory distress syndrome developed in four patients. Oliguria occurred in eight patients. Hyperkalaemia was seen in six patients and four of them underwent emergency haemodialysis. One patient died because of hyperkalaemia on arrival to the intensive care unit. Renal failure was treated with haemodialysis or haemoperfusion in 13 patients. Five patients died because of multiple organ failure and two patients because of sepsis.

Conclusion: Crush syndrome is a life treatening event. The authors believe that early transportation and immediate intensive care therapy would have improved the survival rate.

Crush syndrome is a form of traumatic rhabdomyolysis that occurs after prolonged continuous pressure and characterised by systemic involvement.[1] Extensive muscle crush injury culminating in the crush syndrome is often lethal unless promptly and vigorously treated.[2] The damages are seen after a prolonged period of pressure on a muscle group. The pressure causes necrosis of the muscle, and during revascularisation, diffusion of calcium, sodium, and water into the damaged muscle cells is seen, together with loss of potassium, phosphate, lactic acid, myoglobin, and creatinine kinase. These changes can lead to hyperkalaemia, acidosis, acute renal failure, and hypovolaemic shock.[3 4] Myoglobin induces renal injury by incompletely defined mechanisms. If renal failure develops, haemodialysis is started. The indications for fasciotomy are lack of distal pulse or open lesions. Radical removal of all necrotic muscle is essential when fasciotomy is performed.[3 5]

Crush syndrome is typically encountered in war zones, in mining disasters, after earthquakes, and in industrial and traffic accidents.[4 5] Difficulties with communication and transportation in the disaster often prevent early extrication and therapeutic interventions. Early extrication and administration of intravenous fluids are important in preventing renal failure.[4 7]

At 3 02 am on 17 August 1999, the ground shook violently for 45 seconds under north western Turkey, entombing tens of thousands of sleeping families. It registered 7.8 on the Richter scale. It was called the Great Marmara earthquake. The epicentre was in Izmit, an industrial town about 60 km from Istanbul. In this report we describe the profiles, treatment, and outcome of 18 crush injury patients treated in our intensive care unit.

METHODS

At least 20 000 people died and 30 000 people were injured after the Marmara earthquake. Seven hundred and eighty three patients were transferred to our university hospital, 18 patients were dead on arrival to hospital and 21 patients died during their stay. Twenty five patients were admitted to the intensive care unit (ICU) and 18 of them had crush injury. The patients had been buried under their houses that collapsed in the earthquake. Crush injury was diagnosed on the basis of the presence of swollen limbs and history of limb compression. All patients were admitted to the nearest hospitals and then transferred to our university hospital for advanced care treatment, because intensive care therapy and haemodialysis were not available at those local hospitals. Intravenous fluids were given after salvage in the field or arriving at the nearest hospital, but exact fluid volumes and types could not be recorded.

Blood tests, arterial blood gas analysis, chest radiography, clinical, and neurological examination were performed on admission to ICU. On the basis of suspected chest injury computed tomography (CT) was performed in addition to chest radiography. Pneumothorax, haemothorax, or rib fractures were diagnosed with chest radiography. Heart rate, arterial blood pressure, central venous pressure, and arterial oxygen saturation were monitored hourly. Samples of blood, urine, and wound were sent for microbiological examination.

In hyperkalaemic patients (K^+ 6> mEq/l) glucose and insulin were administered and emergency blood purification (continuous venovenous haemofiltration or haemodialysis) were performed.

Complete blood cell counts and biochemistry tests were performed daily. Urine output was measured hourly. APACHE (Acute Physiologic and Chronic Health Evaluation) II scoring system had been used for predicting outcome with the worst values within first 24 hours. APACHE II score could not be measured in three patients, because they stayed less than 24 hours.

Because it was very difficult to keep complete medical records under the chaotic atmosphere of earthquake some data could not be obtained and are unknown to us.

RESULTS

Table 1 summarises the clinical characteristics of the patients. There were 11 male and 7 female patients, with an average age of 32 (SD13.83) years (range 8–45). Time from earthquake to salvage was 24.10 (22.24) hours (range 45 minutes–72 hours). The interval between first hospital admission to transfer to our intensive care unit was 16.35 (14.42) days (range 0–45). The average admission APACHE II score was 18.06 (3.76) (range 10–25).

Table 1 Patient characteristics

Case	Age	Sex	APACHE II	Time to salvage (h)	Time before admission (day)	LOS (day)	Result
1	45	M	18	3	3	13	S
2	23	F	25	58	4	6	NS
3	18	F		UN	0	0	NS
4	26	M	13	12	5	20	S
5	40	F	10	UN	18	6	S
6	34	M	21	UN	18	1	S
7	21	M	17	14	20	7	S
8	65	F	17	35	10	4	S
9	55	M	17	UN	17	7	S
10	8	M	22	16	2	21	S
11	18	F	17	UN	6	10	NS
12	26	M	23	72	5	16	S
13	36	M	17	8	45	15	S
14	29	M	20	36	4	7	NS
15	26	M	17	1,3	9	1	NS
16	41	M	17	10	35	3	S
17	30	M		24	36	0	NS
18	35	M		UN	41	0	NS

F, female; M, male; UN, unknown; S, survive; NS, non-survive; LOS, length of stay.

Table 2 summarises the laboratory findings and interventions. Myoblobinuria was detected in seven patients.

Almost all patients sustained major injuries that were localised in lower extremities in 16 patients, upper extremities in four patients, and on the chest in four patients. Pelvic, limb, and rib fractures and abdominal injuries were present less frequently. One patient had frontoparietal fracture (case 12), one had traumatic pericardial effusion (case 5), another had pulmonary embolism (case 9) and one patient with a globe perforation also showed signs of appendicitis on admission and had undergone appendicectomy (case 6).

Fasciotomy operations were performed on seven patients. Six patients underwent limb amputations.

The most common type of chest injury was contusion followed by pneumothorax and haemothorax. Twelve patients required mechanical ventilation, because of respiratory failure. One patient received non-invasive (case 9), others received invasive mechanical ventilation. Adult respiratory distress syndrome (ARDS) developed in four patients (case 1, 2, 14, 15). The mean (SD) time on mechanical ventilation was 114.9 (90.3) hours.

Case 3 died suddenly of cardiac arrest attributable to hyperkalaemia in the first hour after admission to ICU.

Thirteen patients developed renal failure. Oliguria occurred in eight patients. Serum creatinine concentrations peaked in 12 patients and the maximum level was 6.04 (4.22) mg/dl on admission to ICU. Hyperkalaemia was seen in six patients and the maximum value was 5.35 (1.23) mEq/l and elevated T waves on ECG were present in five patients. Four of them underwent emergency haemodialysis.

Renal failure was treated with blood purification in these patients. Continuous haemofiltration was used in six patients (arteriovenous in two patients and venovenous in four patients) and haemodialysis was used in seven patients. Serum potassium and creatinine were corrected to normal concentrations within days of ICU care.

Microbiological investigation revealed pseudomonas, *E coli*, proteus and acinetobacter in wound, enterobacter, staphylococcus in blood, and candiada albicans in urine samples.

Five patients died because of multiple organ failure and two patients died from severe sepsis and septic shock.

DISCUSSION

On 17 August 1999, one of the most powerful earthquakes in the century hit the north western part of Turkey. Turkey has a

Table 2 Laboratory findings, interventions

Case	Site of injury	Fasciotomy	Amputation	MV (h)	RF	Max serum K^+	Max serum creatinine	BP	Associated injuries and/or complications
1	Leg (L)+acetabulum			54	–	4.7	2.42	–	ARDS
2	Leg (R)	Leg (R)	Leg (R)	117	+	4.23	17.8	CRRT	ARDS+sepsis
3	Leg(L)+Leg(R)			–	–	6.5			
4	Leg(L)+Arm(L)	Leg (L)		168	+	5.6	7.12	CRRT	Pneumothorax
5	Leg (L)			–	+	5.4	2.2	HD	Pericardial effusion
6	Leg (L)			–	+	4.07	6.06	HD	Appendicitis+globe perforation
7	Leg (L+R)	Leg (L)		29	+	5.4	3.5	CRRT	Cellulitis+pleural eff
8	Leg (L+R)	Leg (L+R)	Leg (L+R)	7	+	4.6	3.2	HD	
9	Leg (L)+Arm(R)+Ribs			50	–	4.4	0.74		Pulmonary embolism
10	Leg (L+R)	Leg (L+R)	Leg (R)	–	+	6.3	4.39	HD	
11	Leg (L+R)			228	+	6.7	6.6	CRRT	Sepsis
12	Leg (L+R)+Arm(L+R)		Arm (L)	288	–	3.7	1.7		Frontoparietal fracture
13	Leg (L)	Leg (L)		227	+	5.5	7.7	CRRT	
14	Leg (L+R)	Leg (L+R)		111	+	3.8	7.8	CRRT	ARDS
15	Thorax			32	+	5.7	7.0	HD	CRF+ARDS
16	Leg (L+R)+Arm(L)		Leg (L)	–	+	8.5	11.26	HD	
17	Leg (L+R)		Leg (L+R)	–	+	6.01	7.2	HD	
18	Leg (R)			3					

CRRT, continous renal replacement therapy; CRF, chronic renal failure; HD, haemodialysis; MV, mechanical ventilation; RF, renal failure; BP, blood purification.

long history of earthquakes and most have occurred along the North Anatolian fault.[8]

In earthquake situations, the timing of emergency search and rescue operations is critical. In the Marmara earthquake, the first of the Turkish rescue teams arrived on site six hours after the shock and the first three international rescue teams took part 16 hours later.[7] Experience shows that extrications after six hours have a low probability of survival. In 1980, in Italy 80% of the people recovered alive were extricated within 12 hours.[9] Alexander *et al* and Armenian *et al* report respectively that survival after six hours and 12 hours is rare.[10 11]

Impassable roads and disrupted communication systems made it difficult to help adequately. In Taiwan, after the Chi Chi earthquake the same communication and transport problems were experienced.[12] Ship or helicopters performed most of the transportation in Marmara earthquake. When traffic is paralysed after an earthquake transportation by helicopter can play an essential part and transportation times can be shortened.[13]

In the past 20 years, crush syndrome has been studied mostly in building collapse situations where limited numbers of patients were treated in fully functional hospitals.[14] Most life threatening injuries sustained by earthquake victims involved limb fracture, renal failure, and chest trauma that need specialised care. In our study the sites of major injuries were similar with previous reports.[15]

Complications of the crush syndrome can be prevented by very early and vigorous treatment. Fluid replacement should start at the site of extrication of the trapped person at a rate of 1.5 litres per hour with isotonic saline. Intravenous fluid infusion, particularly rapid infusion of isotonic saline solution, had been recommended as a prophylactic treatment against the development of acute renal failure.[3 4 7] It has been reported that renal failure was successfully prevented with the start of aggressive fluid infusion within 10 hours of release of the muscle under compression.[7] It is indicated that failures of sufficient administration of intravenous fluids in early phase increase the incidence of renal failure. Shimazu *et al* reported that fluid resuscitation during the initial two days is critical for preventing renal failure.[16] Intravenous fluid infusion had been started after arriving at the nearest local hospital. Despite that, six patients were hypovolaemic when they arrived to our unit.

Hyperkalaemia appears within hours of the rescue and renal failure develops. Patients often die of hyperkalaemia unless they are treated rapidly. Yoshimura *et al* have reported on a patient who died of cardiac arrest because of hyperkalaemia.[17] One of the patients in our study suddenly died of cardiac arrest because of hyperkalaemia. The serum potassium concentration exceeded 6 mEq/l in this patient and there were ECG changes.

It is known that crush syndrome can develop in many people after earthquake. This condition is characterised by oliguric renal failure of rapid onset.[16] In our study, six patients had oliguric form of acute renal failure and seven had myoglobinuric non-oliguric acute renal failure. The mortality from crush syndrome sustained in earthquakes ranges from 13% to 25% when renal failure develops. The occurrence of acute renal failure after rhabdomyolysis decreases the survival of the patients, even with the renal replacement therapy.[18 19] Arterial venous haemodialysis can be used without need for delivery system, pumps, and electric power.[20] In this report continuous arterial-venous haemodialysis, venovenous haemodialysis, and haemodialysis have been used. We did not have enough haemodialysis machines in the ICU and because of that arterial venous haemodialysis was used in two patients.

Renal failure after rhabdomyolysis can be predicted to accompany earthquakes. After the major earthquake of December 1988 in Armenia 600 to 1000 patients required treatment for acute renal failure.[21] Early haemodialysis often cannot be performed after a disaster; prevention of acute renal failure has been a major focus of investigation for many years. Ron *et al* reported that renal failure was successfully prevented with the initiation of aggressive fluid infusion within 10 hours of release of muscle compression.[7] The serum myoglobin concentrations decreased linearly regardless of the method of blood purification used.[22]

Fasciotomy had been performed in seven patients without peripheral pulse as assessed with Doppler flowmetry. Six of these patients were mechanically ventilated. Oda *et al*[6] also assessed the peripheral pulse with Doppler flowmetry to perform fasciotomy. There is debate about performing fasciotomy; some authors suggest the use of fascitomy to prevent the muscle necrosis,[23] whereas others disagree because fasciotomy encourages wound infection.[4] Thus it is difficult to recommend that fasciotomy as the first choice treatment in crush syndrome patients. Johansen *et al* suggested that crush injury and limb ischaemia are primary contributors to the need for limb amputation.[24] In this study six patients had limb amputation. Oda *et al* reported that fasciotomy may have prevented circulatory disturbances and no patient needed limb amputation and no skin lacerations, fractures, or muscle necrosis were detected in the affected limbs despite the severe muscle damage.[6] The possible explanation would be that these patients had been buried under demolished wooden houses but in our study all patients buried under multistorey buildings and the duration of burial was longer in than our patients.

In this study, ARDS developed in four patients. Too much transfusion, sepsis syndrome, oxygen toxicity, pneumonia, disseminated intravascular coagulation can cause ARDS, as shown in a previous study.[25]

The type of nutrition is important in renal failure. Diet should be high energy with carbohydrates together with restriction of potassium intake because of the well known effect of potassium on myocardial function.[26] Special high energy enteral nutrition products were used for renal failure patients in our study.

Early recognition of crush syndrome is important for successful treatment. Under post-earthquake conditions there were difficulties as the large number of casualties needed immediate medical treatment organisation, medical equipment, and drugs. It would be helpful if the first aid team started appropriate fluid resuscitation immediately. Medical records are very important, they must be completed and sent with the patient when transferred.[3 13]

The severity of injuries is important to determine the chance of survival to the trapped victims, as Noji *et al* mentioned previosly.[27] In this study the patients were severely injured.

The patients who need ICU therapy had a high mortality rate.[28] Seven patients died who had needed ICU therapy.

CONCLUSION

The authors expect much bigger earthquakes in Istanbul in the future. Because of that the first priority must be to establish an independent powered short wave communication network and access should be provided for rescue personnel, to large quantities of intravenous fluids to be ready to use with other medical supplies the site of rescue operation. The hospital, especially intensive care units, must be prepared to receive multiple critically ill patients.

Contributors

Oktay Demirkiran initiated and coordinated the study, designed the protocol of the study, participated in data collection, analysis, and writing the paper. Yalim Dikmen, discussed the ideas, participated in analysis, and edited the paper. Tughan Utku, participated in data collection, analysis and writing the paper. Seval Urkmez, participated in data collection and analysis. Guarantor: Oktay Demirkiran.

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