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ORIGINAL ARTICLE

Evaluation of crush syndrome patients with extremity injuries in the 2011 Van Earthquake in Turkey

Sukriye Ilkay Guner and Mehmet Resit Oncu

Aims and objectives. To perform a descriptive analysis of crush syndrome patients with extremity injuries, which will be used as a reference for future disasters.

Background. In disasters like earthquake, cooperation among medical workers is very important for the follow-up and treatment of patients. Knowing the complications that may emerge with the crush syndrome is one of the responsibilities of the nurses.

Design. Descriptive analysis.

Methods. The medical records of patients with crush syndrome following the 2011 Van Earthquake were retrospectively reviewed. The results were compared with the current literature.

Results. Of the 46 patients with crush syndrome who had extreme trauma, 26 (57%) were men, 20 (43%) were women, and the average age was 38·9 ± 12·5. Fasciotomy was performed in 21 of the patients due to progressive compartment syndromes. Amputations were performed in seven patients who had previously undergone a fasciotomy. Sepsis was observed in seven patients, wound infection in 18, pericardial effusion in three and pleural effusion in two. Additionally, femoral fracture was observed in one patient, tibial fractures in five, haemothorax in three, abdominal traumas in seven and pulmonary embolism in one.

Conclusion. Wound care and antibiotic treatment are important to prevent infections in crush injury. In addition to this, dehydration and electrocardiography changes in hyperkalaemia are observed in crush syndrome. Nurses have significant responsibilities to follow up these observations and their implications.

Relevance to clinical practice. The results of this study may provide the basis for developing strategies in future for optimising attempts to rescue and the nurse care planning of survivors with crush injuries and crush syndrome after earthquakes.

What does this paper contribute to the wider global clinical community?

This article offers:

- Assistance to nursing care in patients with crush injury or crush syndrome after natural disasters.

Key words: infection control, nursing care, trauma, wound care

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Introduction

Crush injury is defined as compression of extremities and other body parts. Muscle swelling and/or neurological disturbances are observed in the affected parts of body (Fig. 1). Crush injuries are most commonly seen in lower extremities (74%), followed by upper extremities (10%) and other parts of body (9%). *Crush syndrome* is a localised crush injury with systemic manifestations. These systemic effects are caused by traumatic rhabdomyolysis

Authors: *Sukriye Ilkay Guner*, PhD, Assistant Professor, School of Health, Yuzuncu Yil University, Van; *Mehmet Resit Oncu*, MD, Assistant Professor, Department of Emergency Medicine, Yuzuncu Yil University Medical School Hospital, Van, Turkey

Correspondence: Sukriye Ilkay Guner, Assistant Professor, School of Health, Nursing Department, Yuzuncu Yil Universitesi, Saglik Yuksek Okulu, 65200 Van, Turkey. Telephone: +90 532 6462854.
E-mail: ilkay.guner@hotmail.com

Figure 1 A crush injury of upper extremity.

(destruction of skeletal muscle) and release of potentially toxic muscle cell components and electrolytes into the circulation (Michaelson 1992, Centers of Disease Control & Prevention 2009).

Crush syndrome following great disasters is a common problem. The term 'crush syndrome' describes the problems that arise as a result of rhabdomyolysis caused by trauma (Vanholder *et al.* 2000, Huerta-Alardin *et al.* 2005, Zhang 2012). Hypovolemic shock, acute renal failure (ARF), hyperpotassemia, cardiac arrhythmias and infections can be included among these problems (Ward 1988, MacLean & Barret 1993, Abassi *et al.* 1998).

In disasters like earthquake, cooperation within the health team is very important for the follow-up and treatment of patients. Knowing the complications that may emerge with the crush syndrome is one of the responsibilities of the nurses. In this study, we perform a descriptive analysis of the patients registered at the Van Region Education and Research Hospital following the 2011 Van Earthquake and present their treatment methods and outcomes.

Materials and methods

This study was approved by the local institutional ethical review board. This study retrospectively investigated the hospital records of patients with crush syndrome admitted to the Van Research and Education Hospital following the 23 October 2011 Van Earthquake. Within the first seven days after the earthquake, patient information was obtained from the hospital records, that is, between 23 October–30 October 2011. A total of 1582 patients registered at the hospital following the earthquake. Patients with crush syndrome were found out. Inclusion criteria were as follows: (1) patients with crush injury that caused crush syndrome, (2) patients whose cause of the crush injury was the 2011 Van Earthquake and (3) patients aged above 18 and below 70. Exclusion criteria were as follows: (1) patients who had crush syndrome because of the reasons other than crush injury and (2) patients aged below 18 and above 70.

The demographic data of the patients with crush syndrome were recorded. The patients were followed up clinically, complete blood count was noted, biochemical tests were performed and bleeding parameters were recorded. The affected extremities of the patients were noted, and fasciotomies and amputations performed were recorded according to the extremities involved. The Mangled Extremity Severity Score (MESS) of the patients was determined at registration (Table 1) (Slauterback *et al.* 1994, Sever *et al.* 2006). MESS may be used to decide whether to carry out amputation in patients with injuries related to limb. A score of ≥ 7 points

Table 1 Mangled Extremity Severity Score (MESS)

Types	Characteristics	Injury	Score
1	Low energy	Stab; simple fracture; pistol gunshot wound	1
2	Medium energy	Open or multiple fractures, dislocation	2
3	High energy	High-speed RTA or rifle GSW	3
4	Very high energy	High-speed trauma; gross contamination	4
Shock			
1	Normotensive transiently	BP stable	0
2	Hypotensive transiently	BP unstable and field but responsive to fluid	1
3	Persistent hypotension	In operating room	2
Ischaemia group			
1	None	Pulsatile, no signs of ischaemia	0
2	Mild	Diminished pulses without signs of ischaemia	1
3	Moderate	No pulse by doppler, sluggish cap refill, paraesthesia, diminished motor activity	2
4	Advanced	Pulseless, cool, paralysed numb without cap refill 1	3
Age (years)			
1	<30		0
2	>30–50		1
3	>50		2

indicates the need for amputation (Johansen *et al.* 1990). Following the crush injury, MESS of patients with ARF and those treated with haemodialysis were determined. Moreover, additional problems of patients were recorded, and a descriptive analysis was performed for patients with crush syndrome.

Statistical analysis

Age, sex and MESS of patients and number of patients with ARF were recorded. The number of patients with crush injury, crush syndrome and compartment syndrome was determined. Continuous variables were expressed as means ± standard deviation, and categorical variables were expressed as numbers and percentages.

Results

Crush syndrome with extremity trauma was diagnosed in 46 of 1582 patients (2·91%). Of all the patients with extremity traumas, 26 were men, 20 were women, and the average age was 38·9 ± 12·5 (18–64 years) (Fig. 2). The average of the MESS of 46 patients was 7·6 ± 1·9 (5–12). Seven patients who had a MESS >7 underwent fasciotomy. Eleven patients (23·9%) with crush syndrome died. Fasciotomy was performed in 21 of the patients due to progressive compartment syndromes. Lower-extremity fasciotomy was performed in 17 of the patients, upper-extremity fasciotomy in two and both in two. Amputations were performed in seven patients who had previously undergone a fasciotomy. The laboratory findings, additional problems of patients and medical interventions are shown in Table 2.

Acute renal failure had progressed in 28 of the patients (60·9%) with crush syndromes, and 16 of the patients (34·7%) were haemodialysed. The average serum potassium value was determined to be 6·32 ± 0·5 mmol/dl (5·1–7·3 mmol/dl).

Sepsis was observed in seven patients, wound infection in 18, pericardial effusion in three and pleural effusion in two (Table 3). No statistically significant difference was found for complication development with regard to age and gender ($p > 0·05$). Additionally, femoral fracture was observed in one patient, tibial fractures in five, haemothorax in three, abdominal traumas in seven and pulmonary embolism in one.

Discussion

In the literature, there are few studies with detailed data on patients with crush syndrome. Data of only 30 patients affected by 1990 Iran earthquake were completely described, in which there were 13,888 casualties and 43,390 injuries (Atef *et al.* 1994). Hospital records for the 385 patients with crush syndrome and accompanying ARF following the 1988 Armenian earthquake are incomplete (Richards *et al.* 1989, Tattersall *et al.* 1990, Armenian 1997). In regard to the Hanshin–Awaji earthquake, only incomplete hospital records of 372 patients with crush syndrome were available (Oda *et al.* 1997). In our study, the data of patients with crush syndrome were carefully recorded.

In our study, only 6·5% of the patients with crush syndrome were aged 60 and above and the age range of the patients is similar to those in previous studies on earthquake disasters. The reason for the less number of older people brought to the hospital is thought to result from the fact that they die under the rubble before being brought to the hospital (Tanida 1996, Frink *et al.* 2010).

The indication for a fasciotomy is problematic among patients with crush syndrome. While some authors believe that fasciotomies should be performed because they prevent muscle necrosis, others think fasciotomies should be avoided because they increase the chance of infections (Rush *et al.* 1989, Frink *et al.* 2010, Gormeli *et al.* 2012). In our series, fasciotomy indications include swelling accompanied by bul-

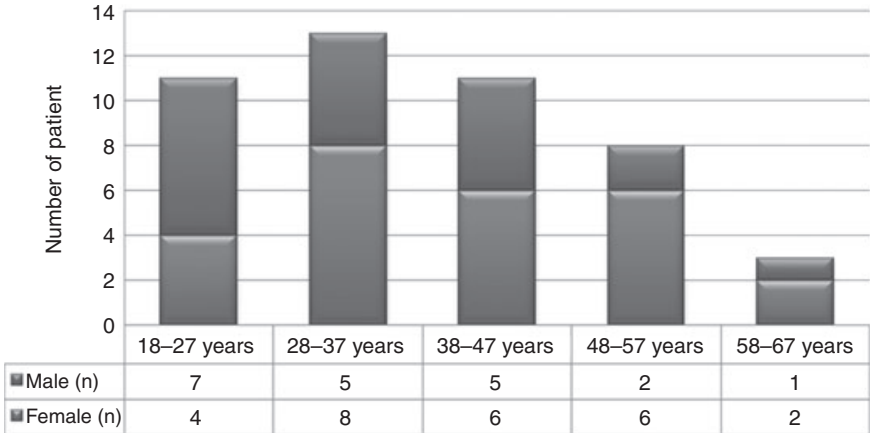

Figure 2 Distribution of patients according to age and gender.

Table 2 Laboratory findings, additional problems of patients and medical interventions

Case	Affected limb	Fasciotomy	Amputation	Acute renal failure	Maximum serum K^+ (mmol/l)	Haemodialysis	Additional problem
1	Lower (L)	–	–	–	6·1	–	–
2	Lower (R)	–	–	–	6·7	–	–
3	Lower (L+R)	Lower (L+R)	–	+	6·6	–	Pregnancy
4	Lower (R), Upper (R)	Lower (R) + Upper (R)	–	+	7·3	+	–
5	Lower (L+R)	Lower (L+R)	–	+	7·1	+	Sepsis
6	Lower (L)	–	–	+	6·2	–	–
7	Lower (R)	–	–	+	5·7	–	Pericardial effusion
8	Lower (L+R)	Lower (L+R)	–	+	7·1	+	Sepsis
9	Lower (R)	Lower (R)	Lower (R)	+	6·1	–	–
10	Lower (R)	–	–	+	6·8	+	–
11	Lower (L)	–	–	+	6·2	+	–
12	Lower (L+R), Upper (R)	Lower (R) and Upper (R)	Lower (R)	+	6·5	+	Sepsis, AT
13	Lower (R)	–	–	–	6·1	–	Pneumothorax
14	Lower (R)	–	–	–	6·3	–	Pericardial effusion
15	Lower (L+R)	–	–	+	6·1	+	–
16	Lower (L+R)	Lower (L+R)	Lower (R)	+	6·4	–	Sepsis, pericardial effusion
17	Lower (L)	–	–	+	6·3	–	Femur fracture, pulmonary embolism
18	Lower (L+R)	Lower (L+R)	Lower (L+R)	+	5·6	–	–
19	Lower (L)			+	5·7	–	–
20	Upper (R)	Upper (R)		–	5·9	–	–
21	Lower (L+R)	Lower (L+R)	Lower (L)	+	6·3	+	AT
22	Upper (L)	Upper (L)		–	6·4	–	–
23	Lower (L+R)			+	6·2	+	Tibia fracture, sepsis
24	Lower (L+R)	Lower (L+R)	Lower (L+R)	+	6·1	+	Tibia fracture, sepsis
25	Lower (R)			+	7·2	–	Cardiac arrhythmia
26	Lower (L+R)	Lower (L+R)		+	6·8	+	Sepsis, AT, tibia fracture
27	Lower (L)	–		+	6·3	–	–
28	Lower (L+R)	Lower (L+R)	Lower (R)	+	6·6	+	–
29	Lower (L+R)	–		+	7·1	+	–
30	Lower (L)	Lower (L)	–	–	6·4	–	–
31	Upper (R)	–	–	+	6·6	–	AT
32	Lower (R)	–	–	–	5·4	–	–
33	Lower (L)	–	–	–	6·0	–	Haemothorax, AT
34	Lower (R)	–	–	–	6·3	–	Haemothorax, AT
35	Lower (R)	–	–	–	6·2	–	–
36	Lower (L+R)	Lower (L+R)	–	–	5·7	–	–
37	Lower (R)	Lower (R)	–	–	5·1	–	–
38	Lower (L+R)	–	–	–	5·3	–	Pericardial effusion
39	Lower (L)	Lower (L)	–	–	6·6	–	–
40	Lower (L+R)	–	–	+	6·0	+	–
41	Lower (L+R), Upper (R)	–	–	+	6·1	+	Tibia fracture
42	Lower (R)	Lower (R)	–	+	7·2	–	Haemothorax, AT
43	Lower (R)	–	–	–	6·6	–	–
44	Lower (L+R)	Lower (L+R)	–	+	6·9	+	Tibia fracture
45	Lower (L)	Lower (L)	–	–	6·7	–	–
46	Lower (L)	–	–	–	6·1	–	Pericardial effusion

R, right; L, left; AT, abdominal trauma.

Table 3 Distribution of complications in patients with crush syndrome

Complications	*n*	%
Hyperpotassemia	46	100
Wound infection	28	60·9
Acute renal failure	18	39·1
Compartment syndrome	16	34·8
Sepsis	7	15.
Pericardial effusion	3	6·5
Pleural effusion	2	4·3

lae in the extremities, ecchymosis, pain in the extremity, faintness, cold, lack of pulse in the extremity, paralysis, myoglobinuria resulting in rhabdomyolysis due to intracompartmental pressure and an intracompartmental pressure >40 mmHg. Measuring the intracompartmental pressure is recommended in the literature for the diagnosis of compartment syndromes (Elliott & Johnstone 2003). However, in our study, measuring the intracompartmental pressure was not possible because usually, large numbers of patients were affected in earthquakes. So, 21 patients who met the above criteria and seven patients who had a MESS >7 underwent a fasciotomy. Patients who underwent a fasciotomy were sent to hospitals in other cities because their wound site care would otherwise be inadequate and because of the problems resulting from the large number of patients admitted for haemodialysis.

There are no standard criteria for decisions to perform an amputation in the early stages of treatment of any of the limbs. A MESS of seven points as a reason for amputation does not appear suitable when assessing injuries to the major vessels in any of the limbs. It is generally accepted that amputation can be performed to control bleeding, to remove the limb that is the source of infection and to avoid crush syndrome (Togawa *et al.* 2006). The rate of amputation after a fasciotomy ranges between 11–38·7% in the literature (Duman *et al.* 2003, Li *et al.* 2009, Safari *et al.* 2011, Guner *et al.* 2013). In our study, the rate of amputation after a fasciotomy was 25%. Fasciotomy is an important predisposing cause in cases developing sepsis (Rush *et al.* 1989, Sever *et al.* 2006, Gormeli *et al.* 2012). In the present study, six of the patients who developed sepsis underwent a fasciotomy.

Hyperkalaemia is a condition that occurs in patients with crush syndrome over a period of hours and results in death due to cardiac arrest if it is not relieved quickly (Greenberg 1998, Parham *et al.* 2006). One patient died as a result of a cardiac arrest related to hyperkalaemia (Patient no. 25, Table 2). The serum potassium value of that patient was 7·2 mmol/dl, and some changes were observed related to hyperkalaemia in the electrocardiography (ECG). Abdominal traumas with crush syndrome were observed in 6·4% of the patients in the Marmara earthquake and in 4·3% of the patients in the Hanshin–Awaji earthquake (Oda *et al.* 1997, Erek *et al.* 2002). The rate of abdominal traumas with crush syndrome among our patients was 13%.

In patients with crush injury, rhabdomyolysis is one of the leading causes of ARF. Other causes of ARF are dehydration and sepsis. ARF developed in 28 (1·7%) of the 1582 patients registered at our hospital after the 2011 Van Earthquake. This rate was 2·7% in the Marmara earthquake, 3·3% in the Hanshin–Awaji earthquake and 0·5% in the Iran earthquake (Atef *et al.* 1994, Oda *et al.* 1997, Erek *et al.* 2002). These lower rates in the Iran earthquake and 2011 Van Earthquake may be related to the fact that there are fewer high-rise buildings in these regions compared with other regions. Moreover, the fact that the 2011 Van Earthquake occurred in the daytime and that people were not in the buildings may be additional reasons for the less number of people trapped under the rubble.

The rate of death among patients with crush syndrome was 40% in the Iran earthquake, 24·7% in the Hanshin–Awaji earthquake and 15·2% in the Marmara earthquake (Atef *et al.* 1994, Oda *et al.* 1997, Erek *et al.* 2002). In our study, the rate of death of patients with crush syndrome was 23·9% (11 patients). Among the patients died, hyperpotassemia was observed in 11 patients, ARF in 5 and cardiac arrhythmia in 1. It appears that the most frequent cause of death was cardiac arrest due to hyperpotassemia and sepsis. We believe that the death rates in crush syndrome can be minimised by transferring patients to the intensive care units to observe ARF follow-up findings and by regular wound care to prevent sepsis development from infection.

The rate of haemodialysis in cases of ARF ranged between 20–60%. Sixteen of the patients with crush syndrome (57·1%) who developed ARF were haemodialysed (Wheeler *et al.* 1986, Corwin *et al.* 1987, Better & Stein 1990, Turney *et al.* 1990, Chertow *et al.* 1999). The rate of death can increase up to 80% among haemodialysed patients in cases of multiple-organ failure, sepsis and cardiovascular and pulmonary problems. Of all 16 patients who were haemodialysed in our hospital, 5 (31·2%) died as a result of concurrent additional problems. O those five, there were two cases of sepsis alone, one abdominal trauma with sepsis, one abdominal trauma and tibial fracture with sepsis and one abdominal trauma alone. Moreover, all these patients underwent a fasciotomy.

Crush syndrome following a great disaster such as an earthquake is an important problem. Hyperkalaemia, ARF

and compartment syndrome which may accompany crush syndrome aggravate the clinical situation. Fasciotomy and amputation can be life-saving when appropriately indicated; however, following these procedures, patients should be monitored for infection and sepsis.

Conclusion

In this study, we found that ARF is the most important complication in patients with crush syndrome. In addition, sepsis and wound infection are other frequently seen complications. Dehydration and ECG changes in hyperkalaemia should also be given due attention in the diagnosis of ARF. Wound care and antibiotic treatment are important to prevent infections. Nurses have significant responsibilities to follow up these observations and their implications.

Relevance to clinical practice

The results of this study may provide the basis for developing strategies in future for optimising attempts to rescue and the nurse care planning of survivors with crush injuries and crush syndromes after earthquakes.

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Disclosure

The authors have confirmed that all authors meet the ICMJE criteria for authorship credit (www.icmje.org/ethical_1author.html), as follows: (1) substantial contributions to conception and design of, or acquisition of data or analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content, and (3) final approval of the version to be published.

Conflict of interest

The authors declare that there are no conflict of interest for this work.

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