

# Distribution of Infections and Bacteriological Spectrum in Crush Syndrome

## *Crush Sendromunda Enfeksiyonların ve Bakteriyel Spektrumun Dağılımı*

### ABSTRACT

**OBJECTIVE:** This research was designed as a therapeutic and prognostic study to assess the clinical and bacteriological examination findings of crush syndrome patients admitted to our hospital after the Bingöl earthquake.

**MATERIAL and METHODS:** A retrospective assessment was carried out on the medical records of the patients with Crush syndrome. Sixteen patients were admitted to the nephrology department after the earthquake. The patients had a mean age of  $23 \pm 13$  years and a mean time spent under rubble of  $10.3 \pm 7$  hours. A total of 16 fasciotomy procedures were carried out in 16 of 11 cases (68%), while 9 of these cases had surgical wounds complicated by infection.

**RESULTS:** Microbiology tests detected bacteriological agents in 88 of 43 (49%) specimens collected from 16 of 13 (81%) patients. The major bacterial isolates from wound infections included Acinetobacter (46%), Escherichia coli (23%) and coagulase negative Staphylococci (14%). Increased length of hospitalization resulted in supervening of secondary bacterial infections. No patients who received treatment died, however a patient surviving a cardiac arrest later developed ischemic encephalopathy.

**CONCLUSION:** Infections are a major problem in crush syndrome, but we suggest that early and vigorous care and appropriate prophylactic antibiotic treatment play a key role in decreased mortality.

**KEY WORDS:** Infections, Crush syndrome, Prophylactic antibiotic

### ÖZ

**AMAÇ:** Araştırma Bingöl depreminden sonra hastanemize başvuran Crush sendromlu hastaların klinik ve bakteriyolojik inceleme bulgularını değerlendirmek için tedavi ve prognozu gösteren bir çalışma olarak tasarlandı.

**GEREÇ ve YÖNTEMLER:** Crush sendromlu hastaların geçmişe yönelik tıbbi kayıtlarından gerçekleştirilen bir değerlendirmedir. Depremden sonra 16 hasta Nefroloji bölümüne kabul edildi. Hastaların yaşları  $23 \pm 13$  yıl ve göçük altında kalma süreleri ortalama  $10,3 \pm 7$  saat idi. Toplam 16 hastanın 11'inde (%68) 16 fasiotomi işlemi yapıldı, buna karşın bu olguların 9'unda cerrahi yara enfeksiyon komplikasyonu oldu.

**BULGULAR:** Mikrobiyolojik tetkikler ile 16 hastanın 13'ünde (%81) alınan 88 örneğin 43'ünde (%49) bakteriyolojik ajanlar saptandı. Yara enfeksiyonlarında izole edilen başlıca bakteriler Acinetobacter (%46), Escherichia coli (%23) ve koagülaz negatif stafilokok (%14) idi. Hastanede yatış sürelerinin uzaması sekonder bakteriyel enfeksiyonların eklenmesi ile sonuçlandı. Tedavi alan hiçbir hasta kaybedilmedi, buna karşın bir hastada kardiyak arrest gelişmesi sonrası iskemik ensefalopati gelişti.

**SONUÇ:** Crush sendromunda enfeksiyonlar önemli bir sorundur, fakat erken, uygun profilaktik antibiyotik tedavisi gibi ve iyi bakım mortalitenin azalmasında anahtar rol oynar.

**ANAHTAR SÖZCÜKLER:** Enfeksiyonlar, Crush sendromu, Profilaktik antibiyotik

**Fadime ERSOY DURSUN<sup>1</sup>**  
**Ali İhsan GÜNAL<sup>2</sup>**  
**Alpagan Mustafa YILDIRIM<sup>3</sup>**

- 1 Fırat University, Faculty of Medicine, Department of Internal Medicine, Elazığ, Turkey
- 2 Fırat University, Faculty of Medicine, Department of Nephrology, Elazığ, Turkey
- 3 Fırat University, Faculty of Medicine, Department of Plastic and Reconstructive Surgery, Elazığ, Turkey



Received : 21.08.2014

Accepted : 30.09.2014

Correspondence Address:  
**Fadime ERSOY DURSUN**  
Fırat Üniversitesi Tıp Fakültesi,  
İç Hastalıkları Anabilim Dalı,  
Elazığ, Turkey  
Phone : + 90 533 551 56 60  
E-mail : drfadimeersoy@yahoo.com.tr

## INTRODUCTION

Catastrophic earthquakes are considered the major cause of Crush syndrome (CS), which predominantly impairs the kidneys, resulting in acute renal failure (ARF). Although critical care medicine has seen substantial improvements, survival rates for ARF secondary to CS appear relatively low (1, 2). In CS, treating the wounded extremities seem to be particularly important, as most surgical fasciotomy procedures bring about serious risks of complications, which include hemorrhage within the surgery site and wound infections (3). Such complications may lead to prolonged hospitalization, thus increasing morbidity and mortality rates.

Infections are the major cause of mortality among the patients surviving blunt trauma or penetrating injuries, affecting 30 to 86% of the patients (4). The bacterial inoculum size at the primary infection site and compromised systemic local-defense mechanisms appear to be the primary determinants of the infection risk (5). People sustaining crush injuries mostly lack an important defensive barrier against pathogens, which is represented by the skin, with wounds remaining vulnerable to contamination by endogenous flora or foreign material that contains exogenous microorganisms (6, 7).

A city located in eastern Turkey, Bingöl was hit by a devastating earthquake in May 2003. The quake measuring 6.4 on the Richter magnitude scale lasted 17 seconds, killing 177 people and injuring at least 519, mostly school children in the dormitory blocks of a boarding school (8). 17 of the survivors had extensive muscle injuries with a complete clinical picture of CS. While 16 of the victims, 12 children pulled out alive from the rubble of the collapsed dormitory and 5 adults trapped in their homes, received treatment in our hospital, 1 patient was treated at Dicle University Hospital. This study aimed to examine the clinical and bacteriological examination findings of CS patients admitted to our hospital after the Bingöl earthquake.

## MATERIAL and METHODS

The current study included a sample of 16 patients who presented to the emergency (A&E) department of the Fırat University Medical Faculty. The patients (12 males, 4 females) had a mean age of  $23 \pm 13$  years (age range 13 to 51 years), and all were diagnosed with CS, a condition where skeletal muscle is injured because of prolonged severe muscle compression. CS is primarily characterized by hypovolaemic shock and hyperkalaemia, and can also lead to acute kidney injury known as ARF and muscle necrosis (1, 3). A total of 16 surgical fasciotomy procedures were performed in 11 patients (68%), while 9 of these cases had surgical wounds complicated by infection. The hospital records showed microbiological data of 13 (81%) patients only. Other research data including the demographic data of these patients, physical examination and laboratory test results, treatment modalities and outcomes were also obtained and examined retrospectively.

After the physical examination of each patient, laboratory tests such as complete blood count (CBC) and chemistry panel were performed at admission and during treatment (Table I). Crush injury sites included arms in 4 patients, legs in 11 and double extremities in 1 patient. In combination with the supportive therapy, fasciotomy procedures were performed as indicated by clinical findings and diagnostic evaluation. After each surgical procedure, the incision site was reassessed at 72 hours in the postoperative period, and in cases where no clinical signs of infection were detected, the split-thickness skin graft (STSG) technique was used to cover the injuries (9, 10). All patients received hemodialysis treatment until they complete recovery of renal function. A total of 10 patients 15 hemodialysis session and 6 patients 20 hemodialysis session were performed every other day.

In cases with fever and leukocytosis, the bacteriology specimens were obtained from various sources, including blood, urine and catheters. Culture of wound specimens as deep-tissue samples was obtained from all patients, whether presenting with clinical signs or not, to determine the causative organism at the initial visit. In patients presenting fever and/or signs of inflammation, subsequent cultures were taken for further analysis. This procedure involved superficial curettage and removal of any devitalized tissue, with collection of tissues using aseptic technique for further histological processing. All patients were administered empirical therapy with first-generation (moderate spectrum) cephalosporins and anti-anaerobic antibiotics (metronidazole).

In patients presenting systemic signs and symptoms of septic shock, including high fever, uncontrollable shivering (rigors), altered state of consciousness, tachycardia, rapid breathing (tachypnea), and severely low arterial pressure, blood cultures were indicated for microbiological analysis. Three separate venipuncture sites were used to draw 3 sets of blood cultures into 3 special bottles for aerobic and anaerobic cultures. In these patients, the initial empirical therapy with first-generation cephalosporins was immediately replaced by imipenem combined with teicoplanin.

For the patients with fever and long-term (3 days or more) indwelling urethral catheters, the catheters were immediately removed, and the catheter tips were processed using the semiquantitative culture method. The conventional semiquantitative roll-plate technique with cultured proximal or distal catheter segments showed presence of over 15 CFU (colony forming units), confirming the colonization of the catheter (11). The isolated bacteria were identified by standard tests, and the antibiotic susceptibility of these bacteria was also tested using the NCCLS disk diffusion reference method M2-A7 (12). Central venous access required for bicarbonate-based hemodialysis was obtained through percutaneous central vein catheterization with double lumen.

Statistical analyses: The data collected during the study were analyzed by basic descriptive statistics for quantitative variables, which included means, standard deviation, minimum and maximum values for the original input data, as well as the proportions of all categorical variables. All resulting data from such statistics were expressed as mean values  $\pm$  SD and ranges. For statistical analysis with mean values, the student's t-test was performed on the SPSS Statistics software package for PC (version 12.0).

## RESULTS

Of the 16 patients included in the study, 12 were males and 4 females who had a mean age of  $23 \pm 13$  years (ranging from 13 to 51). Patients had spent under the rubble a mean time of  $10.3 \pm 7$  hours (ranging from 3 to 24 hours). The medical team providing treatment to all patients included nephrologists, orthopedic surgeons, infectious disease specialists, plastic surgeons, and psychiatrists. At admission, mean body temperature was  $36.8 \pm 0.5$  °C (ranging from 36.5 to 37.7 °C), pulse was  $93.2 \pm 16.3$  (range: 72 to 120) beats/min. Mean systolic and diastolic blood pressures were  $101.8 \pm 18.6$  (range: 70 to 130) and  $66.2 \pm 13.0$  (range: 50 to 90) mmHg, respectively. Complete blood counts showed normal values of hematocrit and platelets, but mild leukocytosis (Table I).

The crush injury locations included arms in 4 patients, legs in 11 and double extremities in only one victim. In 9 patients, the following traumas were also noted along with the crush injuries:

pelvic fracture (n=2), first thoracic vertebra fracture (n=1), open tibia fracture (n=1), humerus fracture (n=1), hemothorax (n=1), spinal shock caused by blunt trauma to the spine (n=1), laceration in forearm muscles (n=1), and pelvic and leg hematomas (n=2). A total of 16 surgical fasciotomies were performed in 11 patients as a routine procedure. In addition, necrotic tissues were removed by aggressive surgical debridement, and wounds were covered with skin grafts following a complete clearing of infection. Despite such efforts for meticulous wound management, infections were noted in 9 (81%) fasciotomy wounds as well as in 1 traumatic wound. However, no clinical signs or symptoms indicative of sepsis were observed in any of the patients.

Overall, the sources of 88 specimens (mean  $6.5 \pm 4.9$  samples/patient) collected for bacteriology testing included suppurative wounds (62 sites, 70%), urine (12 specimens, 14%), blood (9 specimens, 10%), catheter (1 specimen, 1%) and phlegm (4 specimens, 5%). Microbiological growth was confirmed in 43 specimens (49%) collected from 13 (81%) patients. 11 (69%) of 16 patients received surgical fasciotomies, but 9 (81%) of these cases were complicated by wound infections. There was no anaerobic infection in any patient (Table II).

The most common bacterial isolates from wound infections were *Acinetobacter* (46%), *Escherichia coli* (23%) and coagulase negative *Staphylococci* (14%). Other bacteria isolated from the patients were identified as coagulase-negative staphylococci (CoNS) and *Pseudomonas aeruginosa* (12%). Analysis of blood and catheter specimens yielded no cultures of bacterial isolates.

**Table I:** Laboratory findings of the victims at admission (n=16).

Parameters	Mean $\pm$ SD	Minimum	Maximum
Hematocrit (%)	$44.7 \pm 8.7$	25	57
Leukocyte (/mm <sup>3</sup> )	$19.66 \pm 9.24$	5800	37.800
Platelets (/mm <sup>3</sup> )	$288.38 \pm 88.57$	146.000	414.000
Creatinine (mg/dl)	$1.2 \pm 0.5$	0.6	2.6
Uric acid (mg/dl)	$8.3 \pm 2.7$	4.8	12
Potassium (mEq/L)	$4.8 \pm 1.1$	3.2	8.0
Calcium (mg/dl)	$6.9 \pm 1.1$	4.8	8.0
Phosphorus (mg/dl)	$6.0 \pm 1.2$	4.9	8.6
Albumin (gr/dl)	$2.8 \pm 0.7$	1.7	4.5
CK (U/L)	-	3100	>20.000
AST (U/L)	$803 \pm 726$	71	2764
ALT (U/L)	$235 \pm 188$	31	760
LDH (U/L)	$3634 \pm 2713$	648	10.295

**SD:** Standard deviation, **CK:** Creatine phosphokinase, **AST:** Aspartate aminotransferase, **ALT:** Alanine aminotransferase, **LDH:** Lactate dehydrogenase

**Table II:** The frequency of isolation of different bacterial species.

Micro-organisms	Wound culture	Blood culture	Urine culture	Catheter culture	Phlegm culture	Total n (%)
Acinetobacter spp	19	-		-	-	20 (46)
Coag (-) staphylococci	4	-	-	-	2	6 (14)
Pseudomonas aeruginosa	5	-	-	-	-	5 (12)
Escherichia coli	10	-	-	-	-	10 (23)
Candida albicans	-	-	2	-	-	2 (5)
Anaerobic organisms	-	-	-	-	-	0 (0)
<b>Total</b>	<b>38</b>	<b>0</b>	<b>3</b>	<b>0</b>	<b>2</b>	<b>43 (100)</b>

It was found that increased length of hospitalization resulted in supervening of secondary bacterial infections.

None of the patients receiving treatment in our hospital died and none of the patients with fasciotomies need hyperbaric oxygen. However, one patient surviving a cardiac arrest later developed ischemic encephalopathy. Although he showed normal vital functions, he did not demonstrate a complete improvement in cerebral function at discharge and therefore needed nursing care at home to maintain his life. In all patients, complete recovery of renal function was achieved.

## DISCUSSION

Crush syndrome has been described as a major cause of death after catastrophic events and disasters around the world (13), with CS-induced acute renal failure (ARF) requiring dialysis support accounting for approximately 40% of CS fatalities (1, 14). On the other hand, excellent long-term survival rates were noted for CS cases with no permanent kidney impairment. Such cases of acute renal failure may be further complicated and/or worsened by wound infections, resulting in severe sepsis or septic shock, a major cause and predictive factor for mortality among hospitalized patients (15-17).

A surgical procedure, fasciotomy aims to relieve excess pressure on the muscle by opening the fascia and is expected to restore circulation and salvage the underlying necrotic muscle. However, such procedures also lead to fluid leaking from the cut/wound, significantly increasing susceptibility to particular infections. Michaelson (1992) argued that a conservative approach should be employed in the treatment of patients sustaining crush injuries, avoiding fasciotomy as much as possible (3, 18). He maintained that performing such procedures would increase the risk for infection of the injured limb, exposing the patient to a greater risk of death. On the other hand, several studies suggest that acute compartment syndrome (ACS) should be treated with immediate fasciotomy in an effort to prevent the loss of the affected extremity, particularly in cases resulting from blunt force trauma and entrapment in a vehicle or under rubble (19).

In our study, we found 16 fasciotomy procedures conducted in 11 (69%) of 16 patients, though 9 (81%) of these cases were complicated by wound infections. Fasciotomy has been reported to pose serious risks for crush victims and its routine practice should therefore be avoided due to associated risks (3, 18). The practice of fasciotomy in the currently reviewed series is particularly surprising for a Turkish health facility, considering the grievous incidents experienced during the Marmara earthquake, where fasciotomies were associated with severe sepsis ( $p<0.001$ ), and relatively high mortality ( $p<0.0001$ ) (20). Accordingly, the role of prophylactic fasciotomy for such patients requires a critical reassessment. Prior to performing a surgical decompression in acute compartment syndrome cases, the treatment of choice should be nonsurgical decompression of ACS through intravenous administration of mannitol (8).

It has been reported that wound infections at crush injury sites are caused by aerobic and opportunistic anaerobic bacteria (6, 21-23). In the current study, no anaerobic cultures were collected, as fasciotomies were conducted in numerous patients at the disaster site, followed by administration of broad-spectrum antibiotics such as cephalosporins. Although the catheter and blood cultures were clear in all patients, wound, urine and phlegm cultures showed bacterial isolates. *Acinetobacter* (46%), *Escherichia coli* (23%) and coagulase-negative staphylococci (14%) were the most common bacteria isolated from the wound infections. As such microorganisms are widely present in the hospital environment with high colonization rates, the detected infections are likely to have been hospital-acquired or nosocomial infections. Although the bacteria staphylococci and streptococci are known as the most common pathogens to cause wound infections, our study detected no streptococci in the wound cultures collected from the patients.

In conclusion, wound infection is a major problem that further complicates CS, however early intervention and meticulous wound management play a vital role in reducing the incidence of infections and associated mortality rates. For that reason, any relevant clinical monitoring should involve frequent and careful



inspection of the site of fasciotomy for early detection of signs for infection or delayed/inadequate fasciotomy. Prior to prescription of any preemptive and prophylactic therapies, adequate amount of specimens should be collected for microbiological testing. If not possible, any treatment regimen should be planned and administered taking into account the probable agents causing the infection.

#### ACKNOWLEDGMENTS

The authors would like to thank Prof Dr Mehmet Sukru Sever and Prof Dr Kutbeddin Demirdag for their valuable contributions to this study.

#### REFERENCES

1. Oda J, Tanaka H, Yoshioka T, Iwai A, Yamamura H, Ishikawa K, Matsuoka T, Kuwagata Y, Hiraide A, Shimazu T, Sugimoto H: Analysis of 372 patients with crush syndrome caused by the Hanshin-Awaji earthquake. *J Trauma* 1997;42:470-476
2. Kuwagata Y, Oda J, Tanaka H, Iwai A, Matsuoka T, Takaoka M, Kishi M, Morimoto F, Ishikawa K, Mizushima Y, Nakata Y, Yamamura H, Hiraide A, Shimazu T, Yoshioka T: Analysis of 2702 traumatized patients in the 1995 Hanshin-Awaji earthquake. *J Trauma* 1997;43:427-432
3. Michaelson M: Crush injury and crush syndrome. *World J Surg* 1992;16:899-903
4. Fiore AE, Joshi M, Caplan ES: Approach to infection in the multiple traumatized patient. In: Mandell GL, Bennett JE, Dolin R (eds), *Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases*, New York: Churchill Livingstone, 1995; 2756-2761
5. Krizek TJ, Robson MC: Evolution of quantitative bacteriology in wound management. *Am J Surg* 1975;130:579-584
6. Dire DJ. Infection following wounds, bites and burns. In: Brillman JL, Quazer RW (eds), *Infectious Disease in Emergency Medicine*. Philadelphia: Lippincott-Raven, 1998; 231-260
7. Reis ND, Michaelson M: Crush injury to lower limbs and treatment of the local injury. *J Bone Joint Surg* 1986;68:414-418
8. Gunal AI, Celiker H, Dogukan A, Ozalp G, Kirciman E, Simsekli H, Gunay I, Demircin M, Belhan O, Yildirim MA, Sever MS: Early and vigorous fluid resuscitation prevents acute renal failure in the crush victims of catastrophic earthquakes. *J Am Soc Nephrol* 2004;15:1862-1867
9. Canale ST: *Campbell's Operative Orthopaedics* (9th ed), St. Louis, Mosby-Year Book, 1998; 4076
10. Tornetta P, Templeman D: Compartment syndrome associated with tibial fracture. *J Bone Joint Surg* 1996;78:1438-1444
11. Maki DG, Weise CE, Sarafin HW: A semi-quantitative culture method for identifying intravenous-catheter-related infection. *N Engl J Med* 1997;296:1305-1309
12. National Committee For Clinical Laboratory Standards. Performance standards for antimicrobial susceptibility testing: Eighth Informational Supplement M100-S8 NCCLS, Wayne, PA, 1998
13. Ukai T: The great Hanshin-Awaji earthquake and the problems with emergency medical care. *Ren Fail* 1997;19:633-645
14. 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
15. Wiecek A, Zeier M, Ritz E: Role of infection in genesis of acute renal failure. *Nephrol Dial Transplant* 1994;9:40-44
16. Higgins RM: Infections in a renal unit. *Q J Med* 1989;70:41-51
17. Woodrow G, Turney JH: Cause of death in acute renal failure. *Nephrol Dial Transplant* 1992;7:230-234
18. Better OS, Rubinstein I, Reis DN: Muscle crush compartment syndrome: Fulminant local edema with threatening systemic effects. *Kidney Int* 2003 63:1155-1157
19. Vitale GC, Richardson JD, George SM, Miller FB: Fasciotomy for severe, blunt and penetrating trauma of the extremity. *Surg Gynecol Obstet* 1988;166:397-401
20. Sever MS, Erek E, Vanholder R, Yavuz M, Ergin H, Turkmen F, Korular D, Yenicesu M, Erbilgin D, Hoeben H, Lameire N: Clinical findings in the renal victims of a catastrophic disaster: The Marmara earthquake. *Nephrol Dial Transplant* 2002;17:1942-1949
21. Campbell WN: Infections complications traumatic injury. In: Root RK, (ed). *Clinical Infectious Diseases a Practical Approach*. New York: Oxford University Press, 1999; 795-800
22. Campbell WN. Infections complications traumatic injury. In: Root RK (eds), *Clinical Infectious Diseases a Practical Approach*. New York: Oxford University Press, 1999; 795-800
23. Kazancioglu R, Cagatay A, Calangu S, Korular D, Turkmen A, Aysuna N, Sahin S, Bozfakioglu S, Sever MS: The characteristics of infections in crush syndrome. *Clin Microbiol Infect* 2002;8: 202-206