



## RESEARCH

# Multidetector computed tomography findings in patients with abdominal crush trauma due to Kahramanmaraş centered earthquakes

Kahramanmaraş merkezli depremlerde karın ezilme travması geçiren hastalarda multidetektörlü bilgisayarlı tomografi bulguları

Ferhat Can Pişkin<sup>1</sup>, Bişar Akbaş<sup>1</sup>, Ömer Kaya<sup>1</sup>, Hasan Doğru<sup>1</sup>, Hasan Bilen Onan<sup>1</sup>

<sup>1</sup>Cukurova University, Faculty of Medicine, Division of Radiology, Adana, Turkey

### Abstract

**Purpose:** This study aimed to investigate the characteristics of abdominal crush injuries using multidetector computed tomography (MDCT) in survivors of earthquakes centered in Kahramanmaraş.

**Materials and Methods:** Retrospective evaluation was conducted on 255 patients who sustained injuries due to an earthquake centered in Kahramanmaraş and were treated at our hospital. Patients clinically suspected of having abdominal crush trauma underwent MDCT examinations. The presence of abdominal wall injuries, solid organ injuries, free fluid in the abdomen, pneumoperitoneum, and subcutaneous emphysema findings were examined.

**Results:** The median time between injury and MDCT examination was 3 days, ranging from 4 hours to 8 days. Among pediatric and adult age groups, males constituted 42.6% (52/122) and 47.4% (63/133), while females were 57.4% (70/122) and 52.6% (70/133), respectively. The mortality rates for pediatric and adult age groups were 0.4% (1/122) and 4.3% (11/133), respectively. Among patients with fatal outcomes, rates of acute kidney injury, subcutaneous emphysema, spleen injuries, and renal/perirenal injuries were 8.3% (1/12), liver and abdominal wall injuries were 16.7% (2/12), and free fluid in the abdomen was observed at a rate of 33.3% (4/12).

**Conclusion:** Abdominal wall injuries were the most frequently observed manifestations of crush injuries, with renal/perirenal injuries being the most common among solid organs, and liver injuries being commonly seen among intraperitoneal organs. These findings underscore important characteristics of abdominal crush trauma related to earthquakes.

**Keywords:** Multidetector computed tomography, earthquakes, abdominal crush, trauma

### Öz

**Amaç:** Bu çalışmanın amacı, Kahramanmaraş merkezli depremler sonrası abdominal crush gelişen hastaların multidetektörlü bilgisayarlı tomografi (MDBT) bulgularını araştırmaktır.

**Gereç ve Yöntem:** Bu çalışmada, Kahramanmaraş merkezli deprem nedeniyle yaralanan ve hastanemizde tedavi edilen 255 hasta retrospektif olarak değerlendirildi. Klinik olarak abdominal crush travması şüphesi olan hastalara MDBT ile tetkik yapıldı. Hastalar karın duvarı yaralanması, solid organ yaralanması, karın içinde serbest sıvı, pnömoperitoneum ve deri altı amfizemi bulguları açısından incelendi.

**Bulgular:** Yaralanma ile MDBT tetkiki arasındaki ortalama süre 3 gün olup, 4 saat ile 8 gün arasında değişmekteydi. Pediatrik ve yetişkin hastaların sırasıyla, %42,6'sı (52/122) ve %47,4'ü (63/133) erkek, %57,4'ü (70/122) ve %52,6'sı (70/133) ise kadın idi. Pediatrik ve yetişkin yaş gruplarında ölüm oranları sırasıyla, %0,4 (1/122) ve %4,3 (11/133) idi. Ölüm gerçekleşen hastalarda akut böbrek hasarı, deri altı amfizemi, dalak yaralanmaları, renal/perirenal yaralanmaları sırasıyla %8,3 (1/12), karaciğer ve karın duvarı yaralanmaları %16,7 (2/12), ve karın içinde serbest sıvı %33,3 (4/12) oranlarında gözlemlendi.

**Sonuç:** Karın duvarı yaralanması, karın ezilmesinin en yaygın görülen belirtisi iken katı organlar arasında renal/perirenal yaralanma en sık görüleni ve intraperitoneal organlar arasında ise karaciğer yaralanması sıklıkla görülmektedir. Bu bulgular, depremlerle ilişkili karın ezilme travmasının önemli özelliklerini vurgulamaktadır.

**Anahtar kelimeler:** Multidetektörlü bilgisayarlı tomografi, depremler, karın ezilmesi, travma

Address for Correspondence: Ferhat Can Pişkin, Cukurova University, Faculty of Medicine, Division of Radiology, Adana, Turkey, E-mail: ferhatcpiskin@gmail.com

Received: 14.08.2023 Accepted: 11.09.2023

## INTRODUCTION

On February 6, 2023, at 04:17 local time, a powerful earthquake with a magnitude of 7.8 Mw on the Richter scale struck the southeastern region of Turkey and the northern parts of Syria, with its epicenter in Nurdagi, Gaziantep. Subsequently, 9 hours later, at 13:24 local time, another significant earthquake measuring 7.7 Mw occurred 95 km away from the epicenter of the first earthquake<sup>1</sup>. These seismic events caused widespread devastation across an area of approximately 350,000 km<sup>2</sup>, comparable to the size of Germany. Roughly 14 million people, constituting around 16% of Turkey's population, were impacted by these earthquakes<sup>2</sup>. The disaster resulted in a tragic loss of over 57,000 lives (50,000 in Turkey and 7,000 in Syria)<sup>3</sup>. Our university hospital situated approximately 200 km away from the epicenter, with a capacity of 1150 beds, offered medical care to about 3,000 individuals affected by the earthquake. Most patients reached our hospital through road transportation.

In trauma cases, abdominal injuries rank as the third most injured region, contributing to approximately 7-10% of trauma-related fatalities<sup>4</sup>. Blunt abdominal organ injuries result from three primary mechanisms: deceleration, external compression, and crush injuries<sup>5</sup>. Crush injuries involve force compressing the intra-abdominal organs between the abdominal wall and the posterior spine. This excessive compression leads to heightened intraabdominal pressure, which can cause various types of injuries to the abdominal organs<sup>6</sup>.

Missed diagnoses of abdominal injuries are a well-recognized contributor to increased morbidity and mortality in patients initially surviving multiple traumas. Computed tomography (CT) is a highly sensitive and rapid imaging modality for identifying trauma-related injuries<sup>7</sup>. Multi-Detector CT (MDCT) is particularly effective in detecting injuries involving lumen-filled organs and retroperitoneal regions. Consequently, CT is considered the gold standard for identifying intraperitoneal and retroperitoneal injury findings in trauma patients<sup>8</sup>. To our knowledge, there are very few studies in the literature that address MDCT findings of abdominal crush injuries resulting from earthquakes.<sup>9-10</sup> In their study, Chen et al. identified that abdominal earthquake-related crush injuries might be characterized by a high incidence of abdominal-wall soft tissue injury, retroperitoneal kidney injury, and a combination of injuries in the

thorax and pelvis. Our hypothesis was that in patients developing abdominal crush syndrome, MDCT provides important imaging findings, and if well-established, it can serve as a significant guiding tool in future disaster situations.

The objective of this study was to explore the characteristics of abdominal crush injuries utilizing MDCT in survivors of earthquakes centered in Kahramanmaraş, with the aim of enhancing the diagnosis and treatment of patients in the aftermath of such catastrophic disasters.

## MATERIALS AND METHODS

### Sample

The study received approval from our university's ethics committee. Given the retrospective nature of the study, a waiver of patient informed consent was granted. Among the individuals seeking treatment at our hospital (Cukurova University Balcali Hospital), a total of 2809 had sustained injuries in the earthquake.

The majority of these individuals were rescued from debris. The study's inclusion criteria encompassed: a) clinical suspicion of crush abdominal trauma findings verified through MDCT, b) inclusion of patients with concurrent thoracic, spinal, and extremity injuries alongside abdominal crush trauma findings. Patients who had jumped from heights and those involved in road traffic accidents were excluded from the study. Within the timeframe of February 6th to 13th, a total of 255 patients who met the criteria and presented at our university hospital were enrolled in the study. The median duration between the occurrence of injury and the MDCT examination was 3 days, ranging from 4 hours to 8 days.

### CT scan

Scanning with a Siemens Somatom Go-up 128-row MDCT (Siemens, Forchheim, Germany) were conducted. An emergency CT scan without intravenous contrast material was obtained as soon as possible from the upper thorax to the pelvic basement. Because we suspected all victims to have abdominal injuries in combination with acute renal failure due to the massive earthquake, the patients did not undergo contrast-enhanced abdominal CT scans in the earthquake situation. The following scanning parameters were used for both scanners to image the injuries: 120 kV, 250 mAs, 0.5-s gantry rotation time,

pitch of 0.85, collimation of 16 mm × 0.75 mm, 5-mm reconstructed section thickness, 380-mm field of view, and matrix of 512 mm × 512 mm. In patients suspected of solid organ injury, after exclusion of acute kidney injury, additional imaging was performed by intravenous contrast material.

### Image analysis

The acquired images were transferred to the Picture Archiving Communication System (PACS). Subsequently, the images were independently assessed by two radiologists with 5 and 8 years of experience, respectively. In cases where differences in interpretations arose between the radiologists, a consensus was reached through discussions. The patient cohort was categorized into two groups: those aged below 18 years and those aged 18 years and above. Trauma-related findings were examined separately for both age groups, based on imaging results for intra and retroperitoneal organs. Patients were evaluated for indications of abdominal wall injury, the presence of free fluid in the abdomen, pneumoperitoneum, and subcutaneous emphysema. Additionally, alongside abdominal traumas, injuries

identified in other bodily systems were also documented.

### Statistical analysis

The relationship between types of trauma and parameters such as acute kidney injury (AKI) development and mortality was investigated in patients with abdominal crush injuries. Chi-square analysis was performed for age-gender, age-abdominal wall injury, age-subcutaneous emphysema, and age-free fluid in the abdomen parameters. The presence of a relationship in groups with significant differences was tested using the Phi coefficient.  $p < 0.05$  was considered statistically significant. Due to the inadequate distribution of other group numbers, the frequency distribution was provided instead of the 'p' value. Initially, a frequency distribution table was created for all parameters. The analyses were conducted using IBM SPSS v.20.

### RESULTS

The distribution of patients' age and gender, along with the types and patterns of injuries in individuals with abdominal crush injuries, is depicted in Table 1.

**Table 1. The types and distributions of injuries in patients with abdominal crush injuries**

Parametres	Frequencies, n (%)
Age, years	
<18	122 (47.8%)
>18	133 (55.2%)
Death	12 (4.7%)
Acute kidney injury	18 (7.1%)
Gender	
Woman	140 (54.9%)
Man	115 (45.1%)
Renal or Perirenal injury	24 (9.4%)
Pancreas injury	2 (0.8%)
Liver injury	15 (5.9%)
Spleen injury	5 (2%)
Abdominal wall injury	57 (22.4%)
Intraabdominal Free fluid	58 (22.7%)
Pneumoperitoneum	6 (2.4%)
Subcutaneous Emphysema	41 (16.9%)
Age, years	
<18	122 (47.8%)
>18	133 (55.2%)
Death	12 (4.7%)
Acute kidney injury	18 (7.1%)

Within the pediatric and adult age groups, 42.6% (52/122) and 47.4% (63/133) were males, while 57.4% (70/122) and 52.6% (70/133) were females, respectively. In the pediatric and adult age groups, the rates of mortality (fatal outcomes) were 0.4% (1/122) and 4.3% (11/133), with rates of acute kidney injury (AKI) at 0.4% (1/122) and 6.7% (17/133), and renal/perirenal injury rates at 6.6% (8/122) and 12% (16/133), respectively.

While pancreas injuries were absent in the pediatric group, they were observed in 0.8% (2/133) of the adult group. Liver injuries occurred in 4.9% (6/122) of the pediatric group and 6.8% (9/133) of the adult group, whereas spleen injuries were documented in

2.5% (3/122) of the pediatric group and 1.5% (2/133) of the adult group. Pneumoperitoneum was identified in 1.6% (2/122) of the pediatric group and 3% (4/133) of the adult group, with subcutaneous emphysema observed in 12.5% (15/122) of the pediatric group and 13.7% (17/133) of the adult group. The presence of free fluid in the abdomen was 16.4% (20/122) in the age group below 18, while it was 28.6% (38/133) in the age group above 18, with a statistically significant difference ( $p < 0.02$ ). Similarly, abdominal wall injuries were noted as 15.6% (19/122) in the age group below 18 and 28.6% (38/133) in the age group above 18, with this difference also being statistically significant ( $p < 0.015$ ).

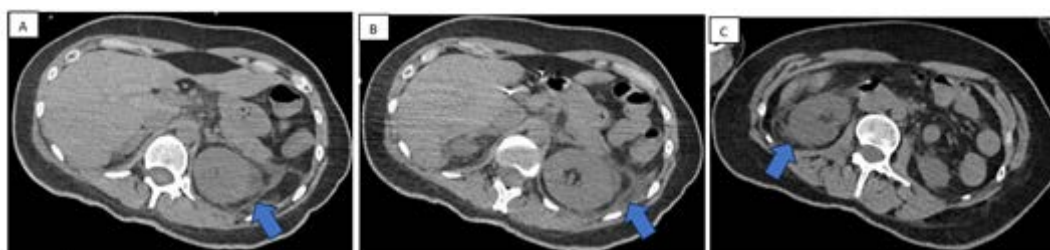


Figure 1 (A-C) A 55-year-old female patient, extracted from under debris and brought to our hospital 32 hours after the earthquake. Due to elevated blood creatinine levels, a non-contrast multidetector computed tomography examination was performed. The obtained images revealed the presence of hematomas (blue arrow) consistent with renal injury in the perirenal fat tissue around both kidneys.

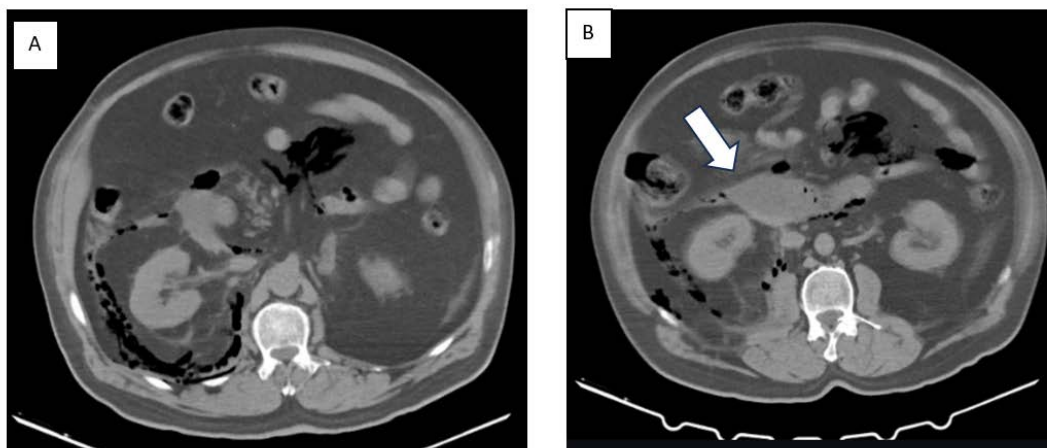


Figure 2 (A-B). A 60-year-old male patient, brought to the hospital 25 hours after the earthquake. Due to the patient's poor general condition and the presence of open wounds on the anterior and posterior abdominal walls, a non-contrast multidetector computed tomography examination was conducted. A. Intraperitoneal and right retroperitoneal free air was observed, likely due to penetrating injury to a hollow organ (stomach or duodenum). B. Additionally, fluid consistent with hematoma related to duodenal injury was observed around the duodenum (White arrow).

Among patients with fatal outcomes, AKI, subcutaneous emphysema, spleen injuries, and renal/perirenal injuries (Figure 1) were observed at rates of 8.3% (1/12), liver and abdominal wall injuries at rates of 16.7% (2/12), and free fluid in the abdomen at a rate of 33.3% (4/12). Within this group, 58.3% (7/12) were females, and 41.7% (5/12) were males. However, pancreas injuries and pneumoperitoneum findings were not present.

In patients with AKI, renal/perirenal injuries and liver injuries were observed at equal rates of 16.7% (3/18), abdominal wall injuries at a rate of 55.6% (10/18), free fluid in the abdomen at a rate of 44.4% (8/18), pneumoperitoneum (Figure 2) at a rate of 5.6% (1/18), and subcutaneous emphysema at a rate of 16.7% (3/18). Notably, spleen and pancreas injuries were not detected among patients with AKI.

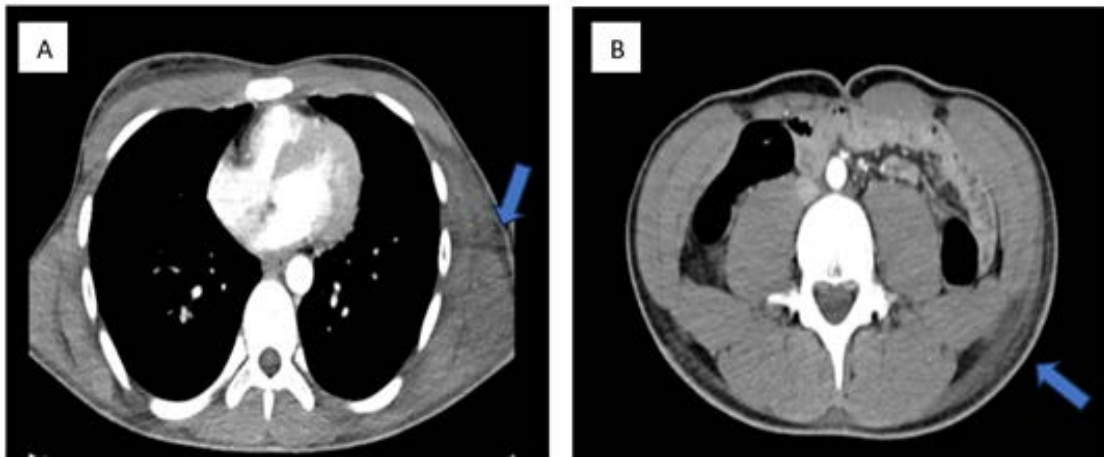


Figure 3 (A-B). A 34-year-old female patient, extracted from under debris and brought to our hospital 12 hours after the earthquake. The obtained images revealed the presence of subcutaneous edema (blue arrow) in the left hemithorax and abdominal wall.

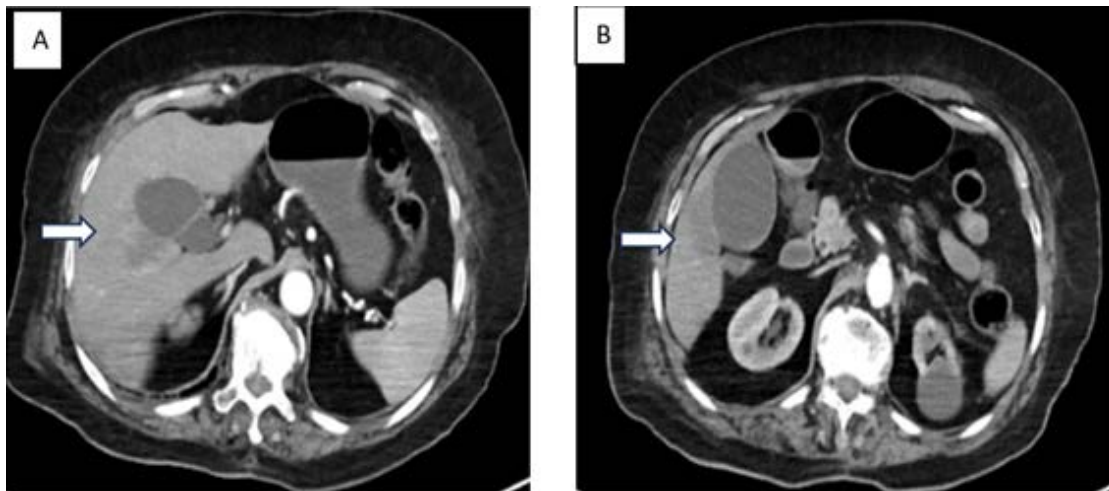


Figure 4 (A-B). A 64-year-old female patient, extracted from under debris and brought to our hospital 32 hours after the earthquake. Due to suspect of solid organ injury, a contrast multidetector computed tomography examination was performed. The obtained images revealed the parenchymal of contusion (white arrow) in the right hepatic lobe.

## DISCUSSION

In earthquakes centered in Kahramanmaraş, a total of 122,007 individuals were injured. Most crush injuries occurred due to collapsing buildings, falling rocks, bricks, or other objects. Among the injured individuals who sought care at our university hospital, abdominal crush injury findings were present in 14% (255/1809) of cases. When compared to the 2008 Sichuan earthquake (2%), 2005 Kashmir earthquake (1%), and the Hanshin-Awaji earthquake (4.3%), abdominal crush injuries were detected at a higher rate in our study<sup>9-12</sup>. The relatively higher prevalence observed in our study could be attributed to the extensive impact of the Kahramanmaraş-centered earthquakes, which affected densely populated cities across a vast area. The disruption of transportation networks and delayed search and rescue operations due to severe winter conditions might have contributed to this situation.

In patients with suspected severe abdominal trauma, such as abdominal pain, guarding, rebound tenderness, bruising, abdominal distension, and absent bowel sounds, an MDCT (Multi-Detector Computed Tomography) scan was performed. The use of MDCT in the evaluation of abdominal crush injuries significantly reduces the initial diagnostic assessment time due to its rapid image acquisition rate<sup>13</sup>. In the initial phase, to assess the possibility of acute kidney injury and considering the potential for triggering renal failure, MDCT scans were conducted without the use of iodinated contrast material.

In this study, abdominal wall injuries were more frequently detected than retroperitoneal and intraperitoneal organ injuries. This could be attributed to the possibility that patients with abdominal wall injuries might have longer survival or that patients with solid organ injuries might have died before reaching the hospital. The most common solid organ injury observed was renal/perirenal injury. In a similar study conducted by Chen et al., retroperitoneal organ injuries were found to be more frequent than intraperitoneal organ injuries among patients with crush abdominal trauma due to earthquakes<sup>9</sup>. In the Marmara earthquake, renal/perirenal injuries were emphasized to be of vital importance not only for predicting the outcome but also for guiding medical treatments<sup>14</sup>.

Furthermore, another study indicated that retroperitoneal organ injuries were more commonly observed among patients with abdominal crush trauma caused by earthquakes compared to those with non-earthquake-related crush abdominal trauma<sup>10</sup>.

Among the intraperitoneal organs, liver injuries have been observed more frequently than spleen injuries. Free fluid in the abdomen stands out as the most observed parameter among all findings. Intestinal perforation or vascular injuries have not been observed in the patient population, which could be explained by the possibility that these patients may have died before rescue was performed. In this study, a mortality rate of 4.7% was found among patients with abdominal crush trauma in the 2023 Kahramanmaraş-centered earthquakes. This rate is lower compared to the Marmara earthquake<sup>15</sup>. This difference might be attributed to the exclusion of severely injured patients from our study or successful medical interventions recorded in the intervening years due to medical advancements. When comparing the adult age group with the pediatric age group, there is no statistically significant difference reported in the literature for parameters such as abdominal wall injury and free fluid in the abdomen.

Our study has certain limitations. Firstly, due to the approximately 200-kilometer distance of our university hospital from the earthquake epicenter, some findings such as intestinal injury, perforation, and vascular injuries might not have been observed, and the incidence of other injuries could be lower. Additionally, the initial absence of contrast material use in MDBT scans might have made it more difficult to detect certain injured organs. Our university hospital was evacuated on the 16th day following the earthquakes due to damage sustained. Some patients were referred to other hospitals and consequently could not be followed up.

In conclusion, crush abdominal trauma is a life-threatening injury of significant concern in earthquakes centered in Kahramanmaraş. Abdominal wall injury is the most observed manifestation, while among solid organs, renal/perirenal injury is the most frequent, and among intraperitoneal organs, liver injury is commonly seen. These findings highlight important characteristics of earthquake-related crush abdominal trauma. In future studies, determining the

clinical significance and impact on survival of the findings detected by MDCT in patients with abdominal crush is important.

**Author Contributions:** Concept/Design : FCP; Data acquisition: HD; Data analysis and interpretation: HBO; Drafting manuscript: BA, FCP; Critical revision of manuscript: HBO; Final approval and accountability: FCP, BA, ÖK, HD, HBO; Technical or material support: HD; Supervision: ÖK; Securing funding (if available): n/a.

**Ethical Approval:** Ethical approval was obtained from the Ethics Committee of Non-Interventional Clinical Trials of the Faculty of Medicine of Çukurova University with the decision dated 02.06.2023 and numbered 134/38.

**Peer-review:** Externally peer-reviewed.

**Conflict of Interest:** The authors declare no conflict of interest.

**Financial Disclosure:** Authors declared no financial support

## REFERECENS

1. USGS. Fault Rupture Mapping of the 6 February 2023 Kahramanmaraş, Türkiye, Earthquake Sequence from Satellite Data. 2023. DOI:10.5066/P98517U2.
2. 1.5 million now homeless in Türkiye after quake disaster, warn UN development experts. UN GENEVA. 2023; published online Feb 21. <https://www.ungeneva.org/en/news-media/news/2023/02/78128/15-million-now-homeless-turkiye-after-quake-disaster-warn-un>.
3. Hussain E, Kalaycıoğlu S, Milliner CWD, Çakır Z. Preconditioning the 2023 Kahramanmaraş (Türkiye) earthquake disaster. *Nat Rev Earth Environ*. 2023;4:287-289.
4. Fabian TC, Bee TK, Cagianos C, Miller PR, Croce MA, Stewart RM et al. Current issues in trauma. *Curr Probl Surg* 2002;39:1160–244.
5. Hughes TMD, Elton C. The pathophysiology and management of bowel and mesenteric injuries due to blunt trauma. *Injury* 2002;33:295–302.
6. Soto JA, Anderson SW. Multidetector CT of blunt abdominal trauma. *Radiology* 2012;265:678–93.
7. Kowal-Vern A, Sharp-Pucci MM, Walenga JM, Dries DJ, Gamelli RL. Trauma and thermal injury: comparison of hemostatic and cytokine changes in the acute phase of injury. *J Trauma Acute Care Surg* 1998;44:325–9.
8. Daly KP, Ho CP, Persson DL, Gay SB. Traumatic retroperitoneal injuries: review of multidetector CT findings. *Radiographics* 2008;28:1571–90.
9. Chen T-W, Yang Z-G, Dong Z-H, Shao H, Chu Z-G, Tang S-S. Abdominal crush injury in the Sichuan earthquake evaluated by multidetector computed tomography. *World J Radiol* 2011;3:135.
10. Chen T, Yang Z, Dong Z, Chu Z, Tang S, Deng W. Earthquake-related crush injury versus non-earthquake injury in abdominal trauma patients on emergency multidetector computed tomography: a comparative study. *J Korean Med Sci* 2011;26:438–43.
11. Mulvey JM, Awan SU, Qadri AA, Maqsood MA. Profile of injuries arising from the 2005 Kashmir earthquake: the first 72 h. *Injury* 2008;39:554–60.
12. Oda J, Tanaka H, Yoshioka T, Iwai A, Yamamura H, Ishikawa K, et al. Analysis of 372 patients with Crush syndrome caused by the Hanshin-Awaji earthquake. *J Trauma*. 1997;42:470-5.
13. Federle MP, Goldberg HI, Kaiser JA, Moss AA, Jeffrey Jr RB, Mall JC. Evaluation of abdominal trauma by computed tomography. *Radiology* 1981;138:637–44.
14. Sever MS, Erek E, Vanholder R, Akoglu E, Yavuz M, Ergin H, et al. Clinical findings in the renal victims of a catastrophic disaster: the Marmara earthquake. *Nephrol Dial Transplant*. 2002;17:1942-9.
15. Erek E, Sever MS, Serdengeçti K, Vanholder R, Akoğlu E, Yavuz M et al. Turkish Study Group of Disaster. An overview of morbidity and mortality in patients with acute renal failure due to crush syndrome: the Marmara earthquake experience. *Nephrol Dial Transplant*. 2002;17:33-40.