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ORIGINAL ARTICLE

Retrospective Study

Radiological findings of February 2023 twin earthquakes-related spine injuries

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Abstract

BACKGROUND

The February 6, 2023, twin earthquakes in Türkiye caused significant structural damage and a high number of injuries, particularly affecting the spine, which underscores the importance of understanding the distribution and nature of vertebral injuries in disaster victims.

AIM

To investigate the distribution of radiological findings of vertebral injuries in patients referred to a major tertiary center during the February 6, 2023 twin earthquakes in Türkiye.

METHODS

With the approval of the institutional ethics committee, 1216 examinations of 238 patients transferred from the region to a tertiary major hospital after the twin earthquakes of February 6, 2023, were retrospectively analyzed for spine injuries.

RESULTS

Spine computed tomography (CT) scans were performed in 192 of 238 patients with a suspected spinal injury, 42 of whom also had an magnetic resonance imaging (MRI). In 86 of 192 patients (44.79%; M:F = 33:53) a spinal fracture was detected on CT and in 33 of 42 patients (78.57%; M:F = 20:13) a spinal injury was found on MRI. Of the 86 patients in whom vertebral injury was detected, fractures were detected in the Denis-B group in 33, Denis-C in 4, Denis-D in 20 and Denis-E in 11 patients. Among the vertebral bodies: 40 "compression fractures", 17 "burst fractures", 5 "translational dislocation fractures", 5 "flexion-distraction fractures" and

58 "prolonged forced fetal posture fractures" were detected. In addition, isolated transverse or spinous process fractures were found in eighteen vertebrae.

CONCLUSION

Our study highlights the prevalence and diverse spectrum of spinal injuries following the February 6, 2023 twin earthquakes in Turkey underscoring the urgent need for effective management strategies in similar disaster scenarios, and emphasizing the "prolonged forced fetal posture" damage we encountered in earthquake victims who remained under the collapse for a long time.

Key Words: Accidental injuries; Compression fractures; Crush injuries; Earthquakes; Spine

Core Tip: In the classification of damages from the earthquakes in Turkey on February 6, 2023, it was found that the injuries were predominantly crush-related rather than escape-related. Observations revealed that patients frequently sustained damage to the thoracolumbar regions due to prolonged fetal positioning under debris. It was determined that a significant portion of patients with spinal canal injuries had damage consistent with the thoracolumbar junction.

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INTRODUCTION

The catastrophic twin earthquakes measuring 7.8 and 7.7 on the Richter scale struck Kahramanmaraş, Turkey, on February 6, 2023, marked a shattering chapter in the region's history, claiming the lives of over 50000 people and leaving thousands more injured[1,2]. The aftermath of these seismic events, saw a saturation of health services, as the scale of the devastation exceeded the capacity of local medical facilities. Unlike other natural disasters, earthquakes impose a disproportionately high toll on human lives, underscoring the urgent need for effective response mechanisms in the face of such crises[3]. Among the myriad of injuries, spinal trauma is of particular concern as it affects a significant proportion of earthquake survivors. In particular, the unique circumstances surrounding these injuries, including the prevalence of crush injuries and falls, pose a particular challenge in diagnosis and treatment[4].

Following the earthquakes, the increase in crush injuries and falls precipitated a wave of spinal trauma that strained already overstretched healthcare resources[5]. Notably, earthquake survivors were found to be at heightened risk of developing crush syndrome, a potentially life-threatening condition characterized by the myonecrosis, rapid hypovolemia and excessive third-space edema[6,7]. In addition, the prevalence of vertebral fractures, often due to the high-force impacts associated with earthquakes, underscored the complex nature of spinal injuries in this context[8].

Compression fractures typically occur due to axial loading, where the vertebral body is crushed under excessive pressure, leading to a wedge-shaped deformity. Of particular concern was the emergence of a specific injury pattern known as "forced prolonged fetal posture", observed predominantly among earthquake survivors and requires specialized diagnostic approaches for accurate assessment[9]. The likely mechanism for a consecutive spine flexion injury due to forced prolonged fetal posture involves excessive and sustained forward bending of the spine, which specifically exerts abnormal compressive forces on the vertebral bodies. This stress can lead to microfractures, compression fractures, or other traumatic injuries to the vertebrae, compromising their structural integrity and resulting in significant spinal damage. Burst fractures, caused by a more severe axial load, result in the vertebral body shattering and dispersing fragments, which can impinge on the spinal canal. Translational dislocation fractures, on the other hand, involve the vertebrae being displaced horizontally, often due to high-energy trauma, leading to severe instability. Flexion-distraction fractures arise from hyperflexion, where the anterior vertebral structures are compressed while the posterior elements are distracted, causing a failure in the vertebral integrity.

The main objective of this paper is to describe the distribution and characteristics of spinal injuries in the survivors of the February 6 twin earthquakes. By analyzing multidetector row computed tomography (CT) and magnetic resonance imaging (MRI) findings from a cohort of individuals who had spinal injuries after the earthquake, we attempt to clarify the incidence and patterns of spinal trauma in this population.

MATERIALS AND METHODS

Study design

The study was conducted following the guidelines of the Declaration of Helsinki and approval for this retrospective study was obtained from the Institutional Ethics Board. Our study included patients who were referred to our hospital from the disaster area during the period from February 6 to February 28, 2023. We included all patients from the disaster area in our study, without considering any age restrictions.

CT and MRI protocol

All CT examinations were performed in the emergency radiology station, *via* Somatom Perspective 64-Slice Siemens® CT device (Erlangen/Germany). CT scan parameters were as follows: Tube voltage: 120 kV, tube current set with optimized automatic exposure control (the ref mAs value of CT was 140 mAs), collimation thickness: 0.6-2 mm, tube rotation time: 0.6-1 seconds and collimated section thickness: 2-5 mm. The iterative reconstruction (ADMIRE, strength 2) with 30 seconds soft tissue and 60 seconds bone kernel was used as a reconstruction algorithm to reduce the radiation dose.

MRI imaging was performed with a Siemens® 1.5 Tesla Aera device (Erlangen/Germany). Imaging parameters for the cervical, thoracic, lumbar and sacral regions included a slice thickness of approximately 3-5 mm, a repetition time of approximately 2000-2500 ms, an Time to Echo of approximately 20-40 ms, a matrix size of approximately 256 × 256 and a field of view of 200-350 mm, depending on the region scanned. The MRI protocol for the spine examination included axial T1-weighted, axial T2-weighted, axial fat-suppressed T2-weighted, sagittal T1-weighted, sagittal T2-weighted, and sagittal fat-suppressed T2-weighted sequences.

Data collection and statistics

All CT and MRI examinations of the spine of these patients were included in the study. The distribution of spinal fractures across the anatomical regions, including the cervical, lumbar, thoracic and sacral regions, was delineated. Fractures were categorized using the Denis, Association for Osteosynthesis (AO), and TLICS classifications[10-13]. Patients were classified according to the AO classification and grouped according to their instabilities, considering the Denis spinal column distributions. To investigate the traumatic effects of prolonged fetal position due to confinement under the debris, we also investigated the incidence of typical consecutive spinal fractures of the thoracolumbar junction, which are more vulnerable and correspond to levels T10-L2.

Statistical analysis included descriptive statistics and incidence calculations to describe the distribution of CT and MRI findings of spinal fractures and to investigate consecutive spinal fractures due to prolonged fetal position.

RESULTS

1216 examinations were carried out on 238 patients who were transferred from the disaster area to our hospital. Of these, 192 patients underwent a CT scan and 42 an MRI scan. Of the 192 CT scans, 163 examinations of the cervical, thoracic and lumbar vertebra were performed, while the remaining scans examined specific anatomical regions based on clinical symptoms.

Of the patients who underwent CT scans, 86 patients had vertebral fractures, of which 63 (73.25%) had multiple fractures and 23 (27.75%) had single fractures. Total fracture number was 287. In addition, 47 patients out of 63 (74.60%) with multiple fractures had consecutive fractures, while 16 patients (25.40%) had scattered fractures. Grouping patients according to TLICS groups of involvement revealed various types of vertebral fractures, including 40 compression fractures, 17 burst fractures, 5 flexion-distraction fractures, 5 translational dislocation fractures, and 58 fractures due to prolonged fetal posture. For examples of vertebral fractures in these patients, please see Figures 1, 2, 3, 4, and 5.

Most injuries occurred in the lumbar region. Sixty-three patients out of 86 patients (73.25%) sustained lumbar vertebra fractures. Furthermore, 140 vertebral fractures were assessed within lumbar region. Of these 63 patients, 33 patients (52.38%) had type B fractures according to the Denis classification, and 26 patients (41.26%) had type A4 fractures according to the AO classification.

Injuries to the thoracolumbar junction (T10-L2) were most common in earthquake victims. Fifty-eight patients had fractures at this level with total 93 fractures. Looking at the distribution of thoracolumbar region injuries based on their vertebral levels, ten (10.75%) fractures were at the T10 Level, sixteen (17.20%) at the T11 level, nineteen (20.43%) at the T12 level, twenty-three (24.73%) at the L1 level and twenty-five (26.88%) at the L2 level. In addition, according to the Denis classification, 27 of them had unstable 3-column fractures in the lumbar region.

Fractures affecting the thoracic vertebrae were identified in 48 out of 86 earthquake victims. Among detected 287 vertebral fractures, 131 were localized to the thoracic vertebrae. Patients with thoracic fractures had different fracture types, with A0 fractures being the most common. Of the 48 patients with thoracic vertebral fractures, 13 patients (27.08%) had thoracic A0 fractures with 44 A0 fractures (33.58%) identified among the 131 thoracic vertebral fractures. According to the Denis classification, nine patients had unstable 3-column fractures in the thoracic region.

No unstable 3-column fractures were observed in patients with cervical vertebral fractures. Ten patients with fractures in the sacral region were grouped according to the Denis zonal distribution classification, and an equal number of zone 2 and zone 3 fractures were observed.

Concomitant fractures in patients with vertebral fractures included ribs (43), upper extremities (10), lower extremities (19), scapulas (11), sternum (4), viscerocranium (6), clavicles (6), and neurocranium (2).

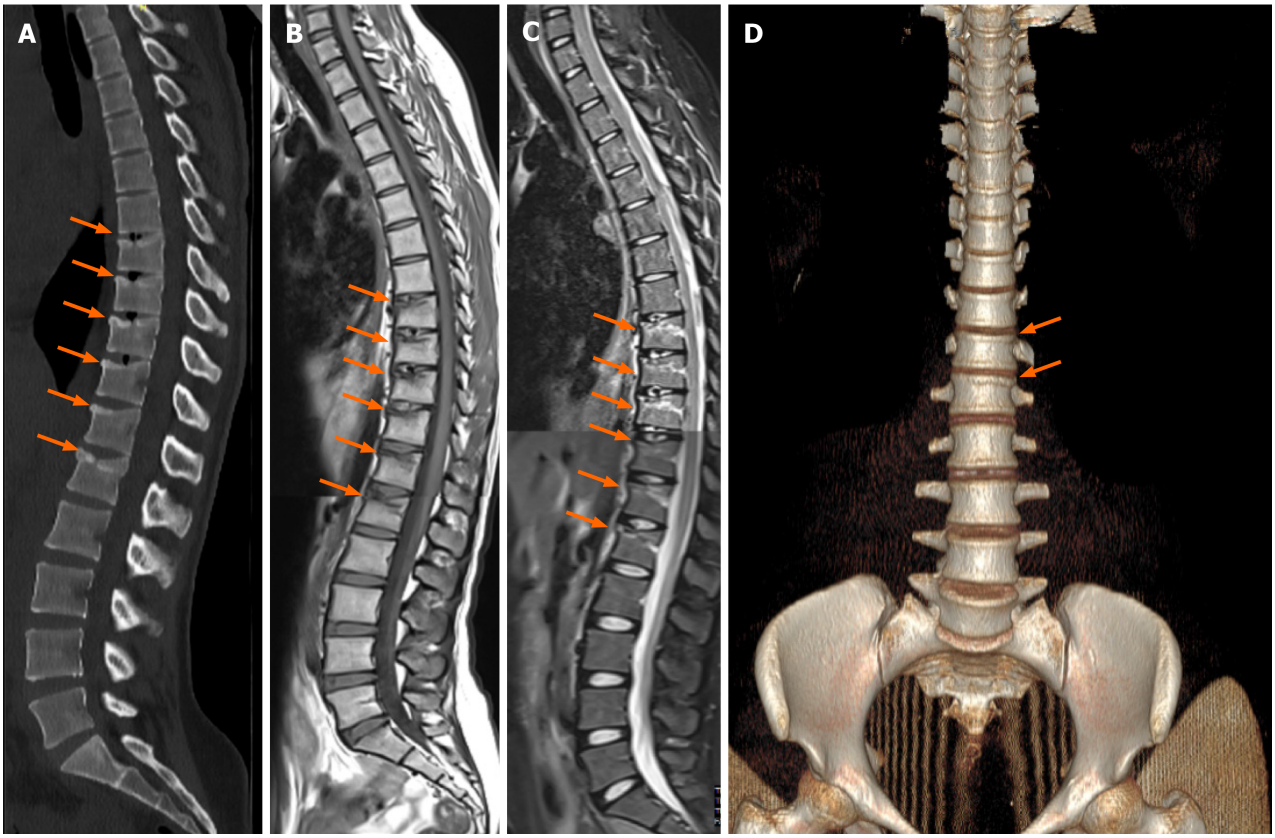

Figure 1 Prolonged fetal posture injury. A 23-year old male who jammed under debris about 15 minutes. A: Computed tomography image reveals T8 to L1 consecutive mild compression fractures (arrows), which corresponds to thoracolumbar area injury; B and C: T1W image and T2-STIR sequence show T8 to L1 vertebrae fracture and edema around them; D: The image of the volume rendering technique shows especially the fractures of the T12 and L1 vertebrae.

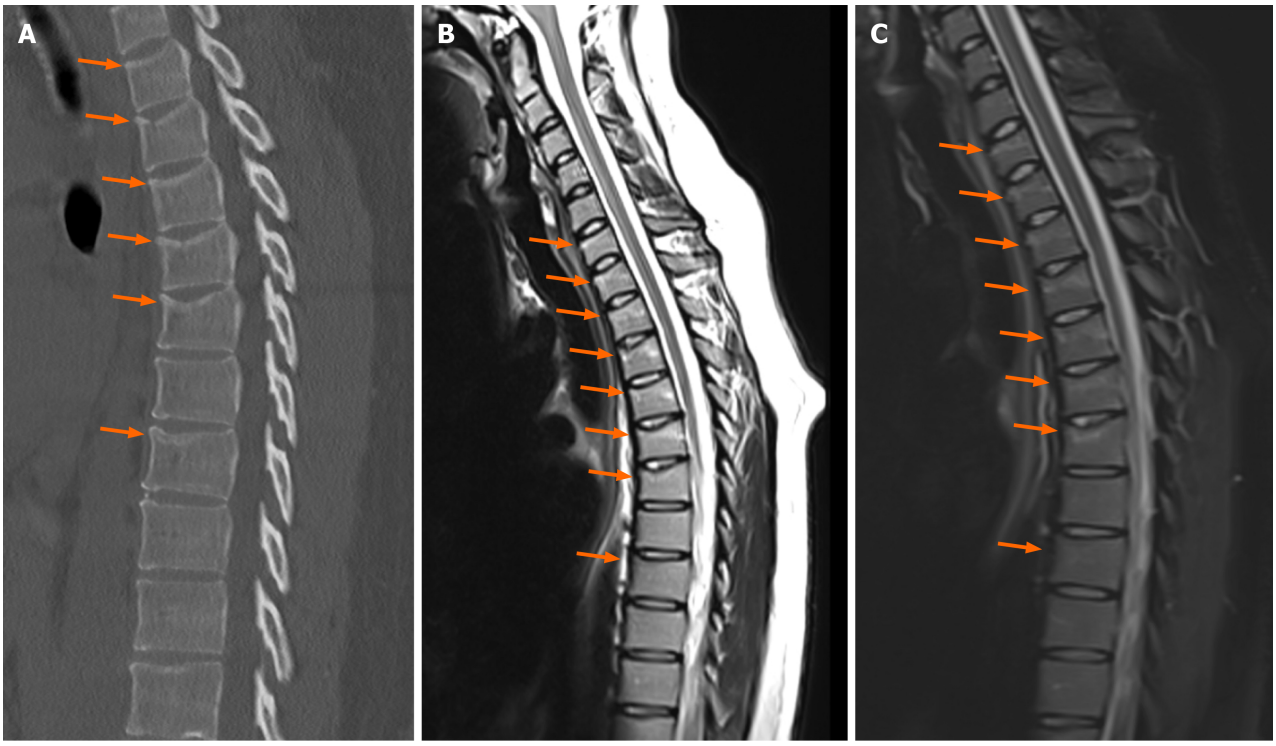

Figure 2 Compression fracture. A 27-year old male who was injured while escaping from the earthquake. A: Computed tomography image reveals T1-T5 vertebrae and T7 vertebra compression fractures (arrows); B and C: T2-STIR and T2W images show C6-T5 vertebrae and T7 vertebra compression fractures (arrows) and edema around them.

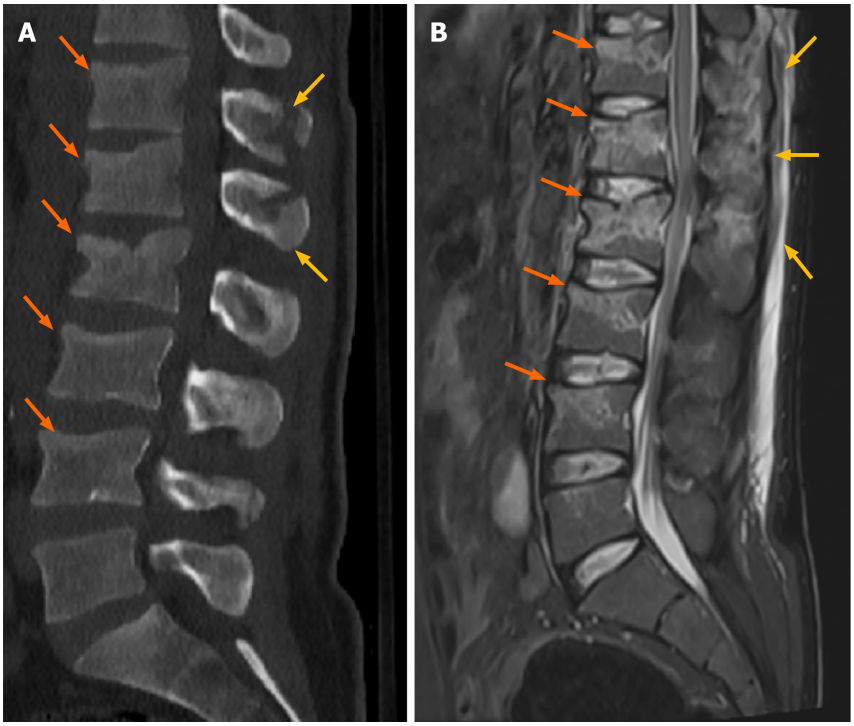

Figure 3 Flexion-distraction fracture. A 35-year old male who jammed under debris about 3 hours. A: Computed tomography image reveals the flexion-distraction type of fracture involving T12 to L4 vertebrae, especially with anteriorly losing height (orange arrows) and distraction of posterior processes (yellow arrows); B: STIR sequence shows fractures of T12 to L4 vertebrae and edema around fractures.

MRI showed retropulsion and narrowing of the spinal canal in 12 patients, and CT showed this in 19 patients. When examining the distribution of fractures causing spinal canal narrowing with retro-pulsed fragments, the most common fractures occurred at the L1 vertebra in 7 patients, followed by the T12 and L2 vertebrae in every three patients, the L4 vertebra in 2 patients, and one patient each in the L3, L5, T11, and T9 vertebrae.

Detailed information on the distribution of fracture types and the positive CT and MRI findings can be found in Tables 1, 2 and 3.

DISCUSSION

The twin earthquakes that struck southeastern Turkey on February 6, 2023, represent a major disaster. Considering the persistent presence of humanity, various types of disasters, especially earthquakes, remain inevitable. A critical aspect requiring attention among earthquake victims is the incidence of vertebral fractures, as documented in the existing literature from various earthquakes worldwide and corroborated by our observations following the twin earthquakes[5, 14]. Analysis of earthquake victims reveals that a substantial portion sustain injuries from being trapped under debris, while others experience vertebral fractures during attempts to escape the earthquake's effects. Li *et al*[15] demonstrated in their research (focused on an earthquake with a magnitude of 8.0) that crush-related injuries constitute the majority of cases; similarly, our study found that most patients were trapped under debris. Consequently, contrast material examination was limited in these patients due to the potential risk of renal damage from crush injuries. Additionally, literature indicates that spinal injuries related to non-earthquake crush injuries are less common[5]. Our demographic analysis of earthquake victims shows a predominance of female patients, mirroring findings from another study and suggesting a possible link to how individuals cope with earthquake hazards. Since crush injuries are the primary cause of trauma rather than escape-related injuries, it is likely that young male victims are better able to avoid injury[5]. This observation aids in understanding the characteristics of the earthquake victim patient group.

In our earthquake-related cohort, the risk of lumbar spinal injury due to retro-pulsed bony fragments was most prevalent, with the highest incidence of fractures occurring in the lumbar region. This finding is consistent with both our observations and results from a study on spinal cord injuries sustained during an earthquake in China (Sichuan, 2008) [16]. Furthermore, another study on earthquakes in China suggests that the extensive coverage area of the lumbar region may contribute to its increased susceptibility to crush injuries, further validating our findings. Our study makes a unique contribution to the existing literature by observing that a substantial proportion of patients exhibited fractures in multiple vertebrae, a finding that aligns with previous studies. However, unlike the study by Dong *et al*[5], which identified minor fractures across multiple widely dispersed areas, our patient cohort predominantly involved consecutive fractures.

A study examining spinal fractures during the Wenchuan earthquake (with a magnitude of 8.0) identified burst and compression fractures as the most prevalent types[15]. Similarly, in our patient group, compression fractures emerged as the most frequently observed fracture type. Additionally, as indicated in the study by Dong *et al*[5], compression fractures

Table 1 Positivity rates and age-gender distribution

Total number of patients	Positive findings (%)	Gender distribution (%)	Mean age	Standard deviation	Median
CT (192)	86 (44.79)	Female: 53 (61.62); Male: 33 (38.37)	45.25	19.56	46.00
MRI (42)	33 (78.57)	Female: 20 (60.60); Male: 13 (39.39)	52.00	19.91	55.00

MRI: Magnetic resonance imaging; CT: Computed tomography.

Table 2 The distribution of injury types

Injury type	Number of patients (86 pts w 287 vertebra fractures) (%)	Mean age	Standard deviation	Median
Compression	40 (46.51)	40.82	20.97	38.50
Burst	17 (19.76)	53.47	18.53	61.00
Translation dislocation	5 (5.81)	49.40	14.97	52.00
Flexion distraction	5 (5.81)	30.20	17.66	26.00
Isolated transverse or spinous process fracture	18 (20.93)	49.88	15.72	52.00
Prolonged fetal posture injury	58 (67.44)	45.22	19.52	48.00

Table 3 The distribution of injury types according Denis-grading system

Denis	Number of patients (86 pts w 287 vertebra fractures) (%)	Mean age	Standard deviation	Median
B	33 (38.37)	40.06	22.04	36.00
C	4 (4.65)	54.00	11.31	54.00
D	20 (23.25)	50.75	18.38	60.00
E	11 (12.79)	43.09	20.95	52.00

may result from direct vertical force or axial loading due to falling objects, indicative of crush injury mechanisms. The high number of compression fractures in our study is correlated with the predominance of patients presenting with crush injuries. Although literature on patients with triple column fractures is limited, our study observed a significant occurrence of these unstable fractures among patients. The prevalence of such fractures in earthquake-related trauma exhibits high-energy trauma characteristics. Upon assessing the likelihood of spinal cord injury in our patient group through clinical evaluation and MRI findings, positive indications were observed in a minority of cases, consistent with findings reported in the literature[16,17]. Furthermore, the absence of myelopathy despite evident spinal canal compression on MRI was correlated with the lack of clinical symptoms in these patients.

The thoracolumbar junction, corresponding to the T10-L2 vertebral levels, is one of the most frequently traumatized areas due to its mechanical vulnerability. This region serves as a transition zone between the thoracic levels, which are stabilized by the ribs and sternum, and the more mobile lumbar levels[18]. Various studies have demonstrated how different body positions affect spinal injuries, and the thoracolumbar region is particularly susceptible to injury in earthquake scenarios[5,9,19-22]. Our research supports this, revealing that the majority of earthquake victims with vertebral fractures had injuries at the thoracolumbar junction (T10-L2). Specifically, when examining patients likely to experience neurological damage due to bony fragment retropulsion into the spinal canal, we found that the majority of these cases, totaling fourteen patients, involved the thoracolumbar junction.

The literature suggests that fractures in the thoracolumbar region occur more frequently due to the kyphotic posture patients often adopt, particularly within the "life triangle," as a protective mechanism against crush injuries[9,23]. This kyphosis-related damage is more likely because earthquake victims tend to minimize their surface area and adopt a hyper-flexed fetal position instinctively to shield themselves from harm. Additionally, the human spine's center of gravity is located anterior to the thoracolumbar junction, further contributing to the tendency of patients to assume this protective fetal position.

The study has several limitations. It is retrospective in nature and confined to a single-center setting. Additionally, while all patients underwent CT imaging, the availability of MRI imaging was limited. A significant limitation of our study is the lack of comprehensive data, as we only have information on the duration patients were trapped under rubble and the time elapsed between their rescue and hospital admission, which limits our ability to investigate the impact of time on vertebral injury patterns and distribution, highlighting the need for further research in this area. Despite these

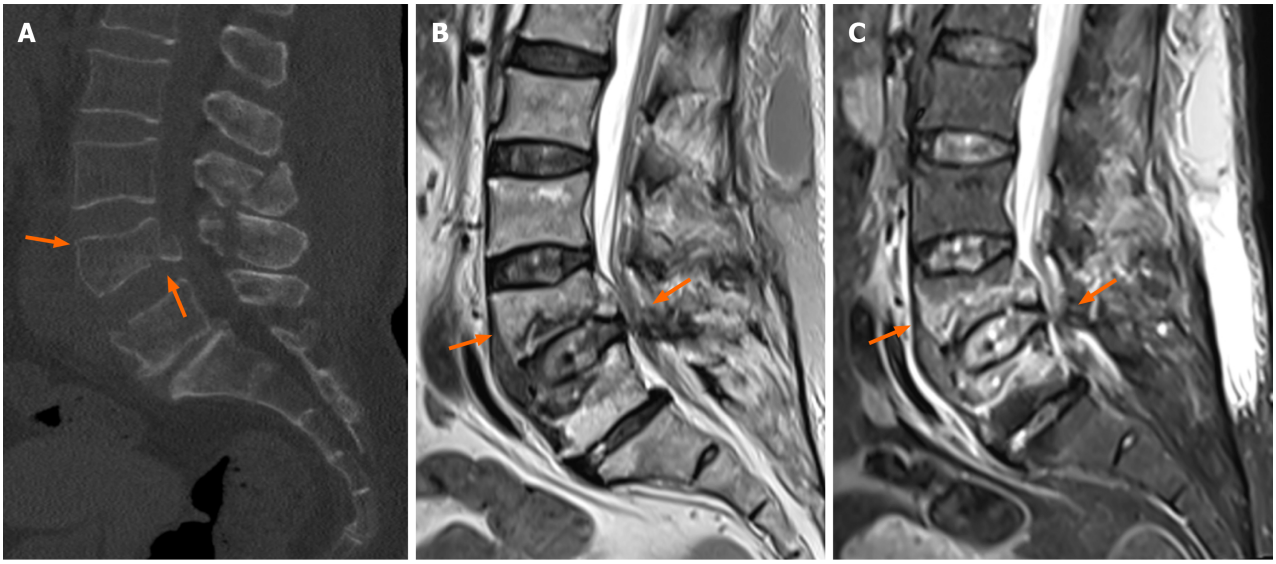

Figure 4 Burst fracture. A 63-year old female who jammed under debris about 48 hours. A: Computed tomography image reveals the burst fracture of the L4 vertebra (arrows) with the loss of height; B and C: T2W and STIR sequence show the retropulsed bone fragment and narrowing of the spinal canal (arrows).

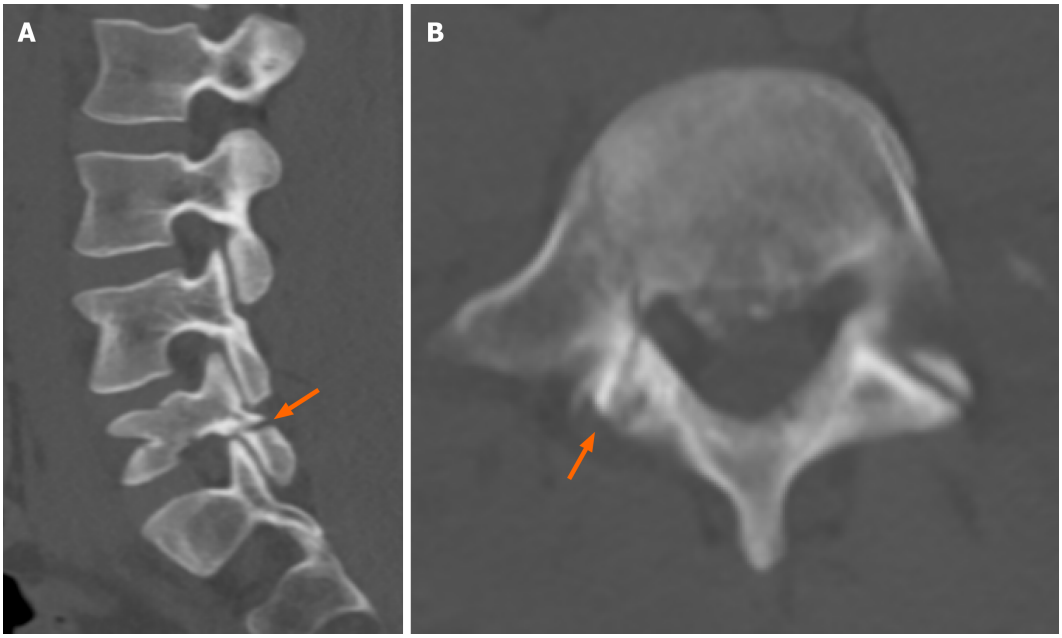

Figure 5 Translation-dislocation fracture. A 52-year old male who jammed under debris about 12 hours. A: Sagittal reformat computed tomography (CT) image reveals the translation type of L4 vertebra fracture (arrow), extending into the right facet joint. B: Axial CT image of the same patient reveals the right transverse process fracture of L4 extending into the right facet joint.

limitations, the study's strengths lie in its comprehensive analysis of vertebral fractures among earthquake victims, particularly its focus on the thoracolumbar junction and the correlation between injury patterns and trauma mechanisms.

CONCLUSION

In the classification of damages from the earthquakes in Turkey on February 6, 2023, it was found that the injuries were predominantly crush-related rather than escape-related. Observations revealed that patients frequently sustained damage to the thoracolumbar regions due to prolonged fetal positioning under debris. It was determined that a significant portion of patients with spinal canal injuries had damage consistent with the thoracolumbar junction.

FOOTNOTES

Author contributions: Bolukçu A designed research and wrote the paper; Erdemir AG performed research and wrote the paper; İdilman IS, Yildiz AE, Çifçi GC contributed figures, analytic tools and analyzed data; Onur MR conceptualized the research; Akpinar E supervised the research.

Institutional review board statement: The study was conducted following the guidelines of the Declaration of Helsinki and approval for this retrospective study was obtained from the Institutional Ethics Board (SBA 24/077).

Informed consent statement: Informed consent was not obtained due to the retrospective nature of the study.

Conflict-of-interest statement: There is no conflict of interest.

Data sharing statement: There is no data to be shared.

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