

Evaluation of patients with traumatic vertebral fractures and accompanying rib fractures in terms of complication development and need for surgery

Travmatik vertebra kırıkları ve eşlik eden kot kırıkları olan hastaların komplikasyon gelişimi ve cerrahi ihtiyacı açısından değerlendirilmesi

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ABSTRACT

Background: The aim of this study was to evaluate patients with traumatic vertebral fractures and accompanying rib fractures in terms of complication development and need for surgery.

Methods: Between January 2019 and September 2022, a total of 173 patients (138 males, 35 females; mean age: 53.0±18.5 years; range, 17 to 95 years) who had vertebral and accompanying rib fractures due to blunt and penetrating trauma were retrospectively examined. The patients were divided into three groups: upper cervical (n=8), lower cervical (n=31), and thoracolumbar (n=134). Among the groups, trauma mechanisms, rib fracture numbers, accompanying thoracic pathologies, complication developments, and need for surgery were compared.

Results: There was a significant difference between men and women in terms of trauma mechanisms (p=0.001). The mean number of accompanying rib fractures was 5.03±3.19. Number of accompanying rib fractures was higher in patients who developed complications compared to those who did not develop complications (p=0.007). Accompanying hemothorax was significantly higher in patients with upper cervical vertebral fractures (p=0.019). Need for spinal surgery to be significantly higher in patients with upper cervical vertebral fractures (p<0.01). Development of complications was higher in patients with burst fracture than in those without (p=0.004). There was a significantly higher need for spinal surgery in patients with burst fractures and lamina fractures (p<0.001 for both).

Conclusion: Identification of risk groups is critical for the management of trauma patients. The type and level of vertebral fractures are related to the presence of hemothorax, the development of complications, and the need for surgery.

Keywords: Complication, rib fracture, trauma, vertebral fracture.

ÖZ

Amaç: Bu çalışmada travmatik vertebra kırıkları ve eşlik eden kot kırıkları olan hastalar komplikasyon gelişimi ve cerrahi ihtiyacı açısından değerlendirildi.

Çalışma planı: Ocak 2019 ile Eylül 2022 tarihleri arasında künt ve penetran travma sonucu vertebra ve eşlik eden kot kırığı olan toplam 173 hasta (138 erkek, 35 kadın; ort. yaş: 53.0±18.5 yıl; dağılım: 17-95 yıl) retrospektif olarak incelendi. Hastalar üst servikal (n=8), alt servikal (n=31) ve torakolomber (n=134) olmak üzere üç gruba ayrıldı. Travma mekanizmaları, kaburga kırığı sayıları, eşlik eden toraks patolojileri, komplikasyon gelişimi ve cerrahi ihtiyaçları gruplar arasında karşılaştırıldı.

Bulgular: Travma mekanizmaları açısından erkekler ve kadınlar arasında anlamlı bir fark vardı (p=0.001). Eşlik eden kot kırığı sayısı ortalama 5.03±3.19 idi. Komplikasyon gelişen hastalarda eşlik eden kot kırığı sayısı, komplikasyon gelişmeyenlere kıyasla daha fazlaydı (p=0.007). Eşlik eden hemotoraks, üst servikal vertebral kırıkları olan hastalarda anlamlı olarak daha fazlaydı (p=0.019). Spinal cerrahi ihtiyacı üst servikal vertebral kırıkları olan hastalarda anlamlı olarak daha fazlaydı (p<0.01). Komplikasyon gelişimi burst kırığı olan hastalarda olmayanlara kıyasla daha yüksekti (p=0.004). Burst kırığı ve lamina kırığı olan hastalarda spinal cerrahiye önemli ölçüde daha fazla ihtiyaç duyuldu (her ikisi için p<0.001).

Sonuç: Travma hastalarının yönetiminde risk gruplarının belirlenmesi önemlidir. Vertebra kırıklarının tipi ve seviyesi hemotoraks varlığı, komplikasyon gelişimi ve cerrahiye ihtiyacı ile ilişkilidir.

Anahtar sözcükler: Komplikasyon, kot kırığı, travma, vertebra kırığı.

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Trauma is among the leading causes of death, particularly in low to moderate-income countries. According to 2019 data from the World Health Organization (WHO), trauma ranks seventh among the leading causes of death in low-income countries and 10th in those with low-moderate and moderate-high incomes.^[1] In the case of Türkiye, 2019 data reported by the Turkish Statistical Institute (TSI) identifies trauma as one of the leading causes of mortality and morbidity, with external injuries and intoxication ranking sixth among all causes of death.^[2]

Traumatic injuries can occur in any part of the body, although thoracic injuries are noted in approximately 60% of all multi-trauma patients and are responsible for 20 to 25% of trauma-related deaths.^[3] Rib fractures are the most common outcome of blunt thoracic trauma, accounting for 21% of all those who present to trauma centers after sustaining such traumas.^[4] Rib fractures can occur within a broad spectrum of severity ranging from a single rib fracture to multiple rib fractures resulting in paradoxical chest wall movement and respiratory failure. They may also cause significant complications such as pneumothorax, hemothorax, pulmonary contusion, pneumonia and respiratory failure.^[5]

Spinal traumas can have devastating medical, psychological, social and financial consequences for both families and communities, given the high rates of associated morbidity and mortality.^[6] Patients with spinal traumas commonly present with multiple traumas, often involving life-threatening injuries.^[7] The treatment objective in the management of spinal trauma is the prevention of neurological injuries, spinal stabilization and the correction of deformities resulting from the trauma.

In the present study, we aimed to evaluate the types of trauma, types and levels of vertebral fractures, number of accompanying rib fractures and thoracic pathologies, surgical procedures and complications in patients with traumatic vertebral fractures and accompanying rib fractures.

PATIENTS AND METHODS

This two-center, retrospective study was conducted at Ege University Faculty of Medicine Departments of Thoracic Surgery and Neurosurgery and Pamukkale University Faculty of Medicine Department of Neurosurgery between January 2019 and September 2022. The data of patients who were followed for vertebral fractures and concomitant rib fractures due to blunt or penetrating trauma were examined. All patients had vertebral fractures and

rib fractures detected by computed tomography (CT). Patients with both displaced and non-displaced fractures were included in the study. Those whose electronic patient records and radiological imaging findings could not be accessed, those in whom the development of complications could not be evaluated due to non-attendance of control visits after discharge (for three months), patients who died in the early period (at the time of hospital admission), patients who were not examined with CT, patients with multiorgan injuries requiring intervention by other clinics, patients with flail chest were excluded from the study. Finally, a total of 173 patients (138 males, 35 females; mean age: 53.0±18.5 years; range, 17 to 95 years) were analyzed retrospectively. A written informed consent was obtained from each patient. The study protocol was approved by the Ege University Medical Research Ethics Committee (date: 09.03.2023, no: 23-3T/1). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data including demographic characteristics, the types of trauma, the type and level of the vertebral fractures, the number of rib fractures, any accompanying thoracic pathologies (pneumothorax, contusion, hemothorax, subcutaneous emphysema), the surgical procedures employed (tube thoracostomy, thoracentesis, bronchoscopy, thoracotomy for hemorrhage control, spinal surgery (instrumentation, laminectomy or instrumentation and laminectomy) and the development of complications were recorded. Patients with rib fractures were followed conservatively. Patients were routinely treated with analgesic treatment and respiratory physiotherapy. Interventions were made in cases of hemothorax, pneumothorax, atelectasis. Patients with flail chest were excluded from the study, as they could need mechanical ventilation or rib stabilization surgery in addition to conservative treatment. In addition, patients were followed with spinal orthosis for vertebral fractures. Spinal surgery was performed in patients with injuries that caused compression or severe stenosis in the canal or in patients with instability. The decision for spinal surgery was made by the neurosurgeon. The patients were subsequently divided into three groups based on their levels of vertebral fracture, specifically: upper cervical (Group 1, n=8), lower cervical (Group 2, n=31) and thoracolumbar (Group 3, n=134 and compared in terms of the trauma mechanisms, the number of rib fractures, the accompanying thoracic pathologies, the development of complications and need for surgical interventions.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 25.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were presented in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. Kolmogorov-Smirnov and Shapiro-Wilk tests were conducted to assess the fit of the data to a normal distribution in the groups, and chi-square and Kruskal-Wallis tests were conducted to evaluate the statistical differences between the groups. A *p* value of <0.05 was considered statistically significant.

RESULTS

An examination of the types of trauma revealed the injuries to be associated with falls from heights in 70 (40.5%) patients, in-vehicle traffic accidents in 46 (26.6%) patients, motorcycle accidents in 20 (11.6%) patients, simple falls in 16 (9.2%) patients, out-of-vehicle traffic accidents in 10 (5.8%) patients, crush injuries in seven (4%) patients, violence-related injury in two (1.2%) patients and gunshot injuries in two patients (1.2%). Distribution of trauma types according to sex is shown in Table 1. A statistically significant difference was observed in the types of trauma of the male and female patients (*p*=0.001).

Vertebral fracture types included transverse process fractures in 100 (57.8%) patients, compression fractures in 70 (40.5%) patients, spinous process fractures in 26 (15%) patients, burst fractures in 18 (10.4%) patients and lamina fractures in 16 (9.2%) patients, although some (*n*=43) patients had multiple vertebral fractures of different types. No significant association was observed between the type of vertebral fracture and the number of rib fractures (*p*=0.762). Complications were significantly more common in patients with burst fractures than in those without burst fractures (38.9% *vs.* 12.9%, *p*=0.004), while no significant difference was noted in the development of complications between patients with compression fractures and those without compression fractures (15.5% *vs.* 15.7%, *p*=0.974), between patients with lamina fractures and those without lamina fractures (14% *vs.* 31.3%, *p*=0.070), between patients with spinous process fractures and those without spinous process fractures (13.6% *vs.* 26.9%, *p*=0.085), and between patients with transverse process fractures and those without transverse process fractures (16.4% *vs.* 15%, *p*=0.797). Spinal surgery was performed in 20 (11.6%) patients. Spinal surgery types were instrumentation in 14 patients, instrumentation and

Table 1. Distribution of trauma types by gender

	Simple falls		Falls from heights		In-vehicle traffic accidents		Out-of-vehicle traffic accidents		Motorcycle accidents		Crush injuries		Violence-related injury		Gunshot injuries	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Male	7	5.1	60	43.5	34	24.6	9	6.5	20	14.5	6	4.3	1	0.7	1	0.7
Female	9	25.7	10	28.6	12	34.3	1	12.5	0	0.0	1	2.9	1	2.9	1	2.9

Table 2. Means number of rib fractures in different trauma types

Rib fracture	Simple falls		Falls from heights		In-vehicle traffic accidents		Out-of-vehicle traffic accidents		Motorcycle accidents		Crush injuries		Violence-related injury		Gunshot injuries	
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	
	5.00±2.60	5.46±3.215	4.30±2.57	7.00±5.75	3.95±2.53	6.14±3.76	6.50±6.36	3.00±1.41								

SD: Standard deviation.

Table 3. Types of trauma across groups

	Simple falls		Falls from heights		In-vehicle traffic accidents		Out-of-vehicle traffic accidents		Motorcycle accidents		Crush injuries		Violence-related injury		Gunshot injuries	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Upper cervical	0	0.0	3	37.5	1	12.5	1	12.5	3	37.5	0	0.0	0	0.0	0	0.0
Lower cervical	2	6.5	8	25.8	15	48.4	4	12.9	2	6.5	0	0.0	0	0.0	0	0.0
Thoracolumbar	14	10.4	59	44.0	30	22.4	5	3.7	15	11.2	7	5.2	2	1.5	2	1.5
Total	16	9.2	70	40.5	46	26.6	10	5.8	20	11.6	7	4.0	2	1.2	2	1.2

laminectomy four patients, and laminectomy in two patients. An analysis of the association between the need for spinal surgery and the type of vertebral fractures revealed a significantly greater need for spinal surgery in patients with burst fractures than in those without burst fractures (61.1% vs. 5.8%, $p<0.001$) and in patients with lamina fractures than in those without lamina fractures (68.8% vs. 5.7%, $p<0.001$). There was no significant difference in the need for spinal surgery between the patients with and without compression fractures (7.8% vs. 17.1%, $p=0.058$), between patients with and without spinous process fractures (10.2% vs. 19.2%, $p=0.185$), and between patients with and without transverse process fractures (15.1% vs. 9%, $p=0.218$).

The mean number of accompanying rib fractures was 5.03 ± 3.19 (range, 1 to 20). Trauma types are summarized in Table 2. The mean number of accompanying rib fractures was significantly higher in patients who developed complications than those who did not (6.93 ± 4.34 vs. 4.68 ± 2.81 , $p=0.007$). In addition, 21.4% of the patients had first rib fractures in our study. Complications were more common in patients with the first rib fractures than in those without, although the difference was not statistically significant (24.3% vs. 13.2%, $p=0.09$). In addition to rib fractures, 94 (54.3%) patients had pneumothorax, 83 (48%) patients had contusion, 80 patients (46.2%) had hemothorax, and 19 (11%) patients had subcutaneous emphysema. Of the patients, 42 (24.3%) underwent tube thoracostomy two (1.2%) underwent thoracentesis, three (1.7%) underwent bronchoscopy and one (0.6%) underwent thoracotomy for hemorrhage control, while 20 (11.6%) patients underwent spinal surgery.

The patients were categorized into three groups based on the level of their vertebral fractures, Group 1 comprising patients with upper cervical (C1-2) vertebral fractures ($n=8$ [4.6%] patients), Group 2 comprising patients with lower cervical (C3-7) vertebral fractures ($n=31$ [17.9%] patients), and Group 3 comprising patients with thoracolumbar vertebral fractures ($n=134$ [77.5%] patients). Eighteen (10.4%) patients had multiple levels injuries both at cervical and thoracolumbar levels.

The most common trauma mechanisms among those who sustained upper cervical vertebral fractures were falls from height (37.5%) and motorcycle accidents (37.5%). The most common trauma mechanism among those who sustained lower cervical vertebral fractures was in-vehicle traffic accident (48.4%), while fall from height was predominant in those with thoracolumbar fractures (44%) (Table 3).

The mean number of rib fractures was 6.00 ± 3.78 in the patients with upper cervical vertebral fractures, 4.48 ± 2.86 in patients with lower cervical vertebral fractures, and 5.10 ± 3.23 in patients with thoracolumbar fractures, indicating no statistically significant difference ($p=0.479$).

A comparison of the groups in terms of accompanying pathologies revealed no significant difference between them in terms of the development of pneumothorax ($p=0.888$). Accompanying pneumothorax was identified at the time of presentation in 62.5% of patients with upper cervical vertebral fractures, 54.8% of patients with lower cervical vertebral fractures and 53.7% of patients with thoracolumbar fractures. The occurrence of accompanying hemothorax was significantly higher in patients with upper cervical vertebral fractures (87.5%) than in those with lower cervical fractures (32.3%) and those with thoracolumbar fractures (47%) ($p=0.019$). In addition, the presence of hemothorax was investigated in patients with isolated thoracic vertebral fractures, as it was thought to be important in terms of hemothorax development. Forty-five of the patients (26%) had isolated thoracic vertebral fractures and 62.2% had hemothorax. This rate was higher compared to other patients (40.6% vs. 62.2%, $p=0.012$). No significant difference was observed between the groups in terms of the presence of accompanying contusions ($p=0.449$). Accompanying contusions were noted at the time of presentation in 50% of patients with upper cervical vertebral fractures, 58.1% of those with lower cervical vertebral fractures and 45.5% of those with thoracolumbar fractures.

Complications developed in 27 (15.6%) patients. These were pleural effusion requiring drainage in seven patients (not present at the first hospital admission), paraplegia in five patients, pneumonia in four patients, respiratory failure in three patients, atelectasis requiring bronchoscopy in three patients, wound infection in two patients, pneumothorax requiring drainage in two patients (not present at the first hospital admission) and prolonged air leak in one patient. Intensive care unit requirement occurred in 27 (15.6%) patients. A comparison of the groups in terms of the development of complications revealed 25% of those with upper cervical vertebral fractures, 22.6% of those with lower cervical vertebral fractures, and 13.4% of those with thoracolumbar fractures developed complications, with no statistically significant difference ($p=0.339$). In addition, when patients with multiple level injuries were compared with others, the development of

complications was higher in those with multiple level injuries (13.5% vs. 33.3%, $p=0.029$).

The groups were also compared in terms of the need for surgical intervention, revealing the need for spinal surgery to be significantly higher in patients with upper cervical vertebral fractures (50%) than in those with lower cervical fractures (22.6%) and those with thoracolumbar fractures (6.7%) ($p<0.001$). Considering patients with multiple level injuries were compared with others, the need for spinal surgery was higher in those with multiple level injuries (44.4% vs. 7.7%, $p=0<0.001$). The proportion of patients requiring thoracic surgical interventions (tube thoracostomy, thoracentesis, bronchoscopy, hemorrhage control) was 25% among those with upper cervical vertebral fractures, 12.9% among those with lower cervical vertebral fractures and 13.4% among those with thoracolumbar fractures. No significant difference was observed between the groups in terms of their need for thoracic surgery ($p=0.116$).

DISCUSSION

Traumatic vertebral fractures can lead to severe disabilities, and can have profound physical, psychological, social and economic consequences. Taking into account the risk of permanent sequelae, the consequences can impact not only the affected person, but also their family and the broader community, thus elevating vertebral fractures to the status of a significant public health problem. From an epidemiological standpoint, young males are at a higher risk of vertebral injuries.^[8] Similarly, the majority of patients in the present study were male, accounting for 79.8%.

The primary trauma mechanisms leading to vertebral fractures vary from country to country, with motor vehicle accidents being the most common cause of spinal injuries in developed countries (35-53.8%), while falls from height top the list in developing countries, accounting for 37.9 to 63%.^[9] In a study conducted by Schinkel et al.,^[10] motor vehicle accidents were identified as the most common cause of vertebral injuries, accounting for 49% of the total, followed by falls from height at a rate of 20%. In a study conducted by Aghakhani et al.,^[11] the primary mechanisms behind fractures were falls from height, accounting for 63.2%, followed by motor vehicle accidents with 30.8%. In the present study, traffic accidents were examined by dividing them into three groups: in-vehicle traffic accidents, out-of-vehicle traffic accidents and motorcycle accidents. Therefore, falling from a

height was given as the most common trauma type with 70 patients. If we gather different types of traffic accidents under the title of vehicle accidents, there are vehicle accidents in a total of 76 patients and it can stand out as the most common trauma type. In the present study, the leading trauma mechanism was motor vehicle accidents, accounting for 44% of the total (26.6%, in-vehicle traffic accidents; 11.6%, motorcycle accidents; 5.8%, out-of-vehicle traffic accidents), followed by falls from height in 40.5%. Trauma mechanisms also differed between the males and females in the sample, within-vehicle traffic accidents being the most common trauma mechanism in females, followed by falls from height in 28.6%, while the most common trauma mechanism in males was falls from height, accounting for 43.5% of the incidents, followed by in-vehicle traffic accidents in 24.6%, indicating a statistically significant difference between males and females.

The localization of the injured segment, fracture type and injuries accompanying spinal injury are significant in vertebral injuries. Previous studies have identified thoracolumbar fractures as the most common type of spinal injury, accounting for 50 to 90% of all such injuries.^[12,13] The distribution of the level of such injuries varies between developed and developing countries. In a review by Chiu *et al.*,^[9] the level of injury was reported as 41.6 to 75% cervical, 16 to 36% thoracic, and 9 to 17.6% lumbar in developed countries, while in developing countries, these rates were reported as 4.8 to 47.2% for cervical injuries, 19 to 34.6% for thoracic injuries and 13.3 to 59.4% for lumbar injuries. In the present study, the patients were divided into three groups according to fracture level, being upper cervical, lower cervical or thoracolumbar. Among the patients in the present study, 22.5% had cervical fractures (4.6% upper cervical; 17.9% lower cervical), while 77.5% had thoracolumbar fractures, which is consistent with literature.

Thoracic injuries are the most common type of injury accompanying traumatic vertebral fractures. In a study conducted by Wang *et al.*,^[14] traumatic vertebral fractures were reported to be accompanied by thoracic injuries in 41% of the patients. In the present study, the characteristics of patients with vertebral fractures occurring concurrently with rib fractures revealed no significant association between the level of vertebral injury and the number of fractured ribs ($p=0.479$). In a subsequent examination of the possible relationship between the level of

vertebral injury and the presence of pneumothorax, hemothorax and contusion in the present study, no significant association was found between the level of injury and the presence of pneumothorax and contusion ($p=0.888$ and $p=0.449$, respectively), while concurrent hemothorax was noted in 87.5% of the patients with upper cervical, 32.3% of the patients with lower cervical and 47% of the patients with thoracolumbar fractures. The rate of concurrent hemothorax was significantly higher in those with upper cervical fractures ($p=0.019$), which could be attributed to the frequency at which upper cervical fractures, which are often encountered in young adults, are associated with severe trauma. In a study conducted by Watanabe *et al.*,^[15] high-energy trauma involving hyperextension of the neck in young adults was identified as the most common cause of upper cervical vertebral injuries.

In the present study, we also investigated the factors influencing the development of complications and the need for surgical interventions in patients with vertebral fractures and concurrent rib fractures but revealed no significant association between the level of vertebral fracture and the development of complications. The complications that occurred in the patients included in our study were pleural effusion, pneumothorax, atelectasis, infection, respiratory failure and paraplegia. In the management of complications, drainage was applied for pleural effusion and pneumothorax, and bronchoscopy was performed in patients who developed atelectasis. Patients were treated with appropriate antibiotics for infection. Patients who developed respiratory failure were taken to intensive care and provided respiratory support when necessary. That said, the rate of complications was found to be higher in patients with a greater number of rib fractures ($p=0.007$). In another study by Kozanlı and Güler *et al.*,^[16] increasing the number of rib fractures after trauma increased morbidity and hospital stay. It was thought that the reason for this was that patients with a higher number of rib fractures generally had a history of more severe and high-energy trauma. Furthermore, an examination of the relationship between the type of vertebral fracture and the development of complications revealed a higher rate of complications in patients with burst fractures than those without such fractures ($p=0.004$), while no such significant relationship was found between other fracture types and the development of complications. In addition, when patients with multiple level injuries were compared with others, the development of complications was higher in

those with multiple level injuries (13.5% vs. 33.3%). The need for spinal surgery was significantly higher in patients with upper cervical fractures ($p < 0.01$) and the need for spinal surgery was significantly higher in patients with burst and lamina fractures than those without such fractures ($p < 0.001$). Burst fractures have been associated with high-energy vertebral injuries.^[17] The authors believe that the greater need for spinal surgery in patients with burst fractures may be attributed to a higher rate of complications in such patients. The study revealed no significant association between the need for thoracic surgical intervention and both the level and type of vertebral fracture.

In our study, the characteristics of patients with traumatic vertebral fractures and concomitant rib fractures who may be at higher risk for the development of complications and the need for surgical intervention were revealed. Identification of high-risk groups is of utmost importance, as these patients require close follow-up. Patients at high risk for complications and the need for surgical intervention should be hospitalized and closely monitored. Necessary precautions should be taken to prevent complications and if complications occur, rapid intervention should be performed. For rib fractures, appropriate analgesic treatment and respiratory physiotherapy are critical in preventing complications.^[18,19] In addition, rapid detection of the need for surgery and early intervention in patients with vertebral fractures are important to avoid permanent neurological deficits.^[20]

The main limitations to the present study are its retrospective design and relatively small sample size. In addition, the study was conducted in two centers. Further multi-center, large-scale studies are needed to improve the existing literature on this subject.

In conclusion, our study results showed that the types of trauma in patients with traumatic vertebral fractures and accompanying rib fractures differed between women and men. Furthermore, the rate of concurrent hemothorax was significantly higher in patients with upper cervical fractures, while those with burst fractures and a higher number of fractured ribs were at a greater risk of developing complications. Taken together, vertebral fractures localized to the upper cervical segment and the presence of burst or lamina fractures increase the need for spinal surgery significantly. Considering the physical, psychological, social and economic consequences of vertebral fractures, the identification and management of patients at a higher risk is crucial.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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