Research Square

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Image Classification of Osteoporotic Vertebral Fracture with Endplate-disc Complex Injury

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Abstract

Background The purpose of this study was to observe the condition of osteoporosis vertebral fracture(OVF) combined with endplate-disc complex (EDC) injury through MRI and CT, and to classify the degree of EDC injury according to the changes in the signal and morphology of the EDC on the image.

Methods A total of 479 cases of OVF were included in this study. Baseline data were recorded. We investigate the incidence of EDC injury, observed the morphology and signal changes of EDC injury through MRI and CT, and divided it into grades 0-4 according to the severity of injury.We compared whether there were differences in the degree of EDC injury among different vertebral fractures, bone mineral density(BMD), and severity of vertebral fractures.

Results Among 479 patients, 321 cases had EDC injury adjacent to fractured vertebral body. Among them, 158 cases were grade 0, 66 cases were grade 1, 72 cases were grade 2, 78 cases were grade 3, and 92 cases were grade 4. The degree of EDC injury combined with thoracolumbar vertebral fractures was more serious than that of thoracic and lumbar vertebral body fractures.Vertebral fractures with severe osteoporosis were combined with more severe EDC injury. The more severe the vertebral fracture, the more severe the combined EDC injury.

Conclusion This study found that the incidence rate of EDC injury reached 67.0%. To patients with OVF, severe osteoporosis, and severe fractures in the thoracolumbar segments often have more severe EDC injury.

Background

With increased aging of the global population, osteoporosis is threatening greater numbers of people or is a more frequent problem. Osteoporotic vertebral fracture (OVF) is one of the most common sequelae of osteoporosis. It often leads to lower back pain and spinal deformity, which serious affects the patients' quality of life[1–3]. Percutaneous kyphoplasty(PKP) has become one of the main methods for the treatment of OVF[4–9]. However, the operation is focused mainly on the fractured vertebral body itself, ignoring the treatment of adjacent injuried endplate-disc complex(EDC)[10–11]. The EDC has important functions such as maintaining the stability and integrity of the spine, protecting the spinal nerves, absorbing shocks, and dispersing axial load. When the trauma acts on the vertebral body, it often causes injury to the adjacent EDC at the same time. As the human body's largest blood-free tissue, the injury of EDC often accelerates the disc degeneration, leads to chronic spinal instability and even secondary kyphosis[12–14]. Sander et al. [15] classified vertebral body fracture combined with intervertebral disc(IVD) injury based on the MRI changes of IVD morphology and signal. However, due to their small sample size, they did not include OVF combined with IVD injury, so this classification is not applicable to the combined injuries. Although Fujiwara T et al. [16] observed IVD injury in patients with OVF according to the Sander et al. grading standards, the injury mechanism and degree of IVD injury in OVF may be different from those with normal bone mass, and thus unsuitable for OVF combined specific classification of EDC injury. Ghanem N et al.[17] found that magnetic resonance imaging(MRI) is an effective non-invasive method for diagnosing IVD injury. Although MRI is more sensitive to signal changes caused by IVD injury, it is less sensitive to endplate fractures. Because the endplate is an important part of the EDC, its treatment is as important as the treatment of vertebral fractures. Computed tomography(CT) multiplanar reconstruction(MPR) technology can clearly reveal endplate injury, so the main purpose of this study is to combine MRI and CT to observe the condition of OVF patients with EDC injury, and perform image classification according to the degree of injury, in order to improve communication between spine surgeons and radiologists as well as facilitate clinical decision-making in spine surgery.

Methods

The study was authorized by the Ethics Committee of the Affiliated Hospital of Southwest Medical University.

Patient Population From August 2017 to August 2020, 479 patients diagnosed with an acute OVF of thoracic or lumbar vertebrae were reviewed at the orthopedics department of the Affiliated Hospital of Southwest Medical University. All data were retrospectively reviewed based on medical records and billing statements. All patients had standard thoracolumbar anterior and lateral plain radiographs (Ziehm Solo, Ziehm imagine GMBH, Germany), plain CT scan and MPR images of the fracture level (LightSpeed VCT, GE Healthcare, IN), and MRI of the whole spine (Signa HDe, GE Healthcare Japan, Tokyo). The inclusion criteria were as follows: (1) clinical manifestations of different degrees of waist and back pain, pain aggravated by turning over or getting up; (2) no signs or symptoms of spinal cord or nerve root damage in the corresponding fracture segment; (3) presence of osteoporosis as determined by dual energy X-ray absorptiometry; (4) single vertebral body fractures on MRI with low signal intensity on T1-weighted imaging, high signal intensity on T2-weighted imaging, and high signal intensity on short TI inversion recovery(STIR). The exclusion criteria were as follows: (1) serious spinal instability caused by pedicle fracture; (2) symptomatic neurologic injury; (3) non-OVF conditions, such as tumors or infectious diseases, confirmed by pathological examination.

Image classification of EDC injury in OVF patients

To differentiate acute OVF from vertebral body fat deposits, chronic OVF, vertebral body hemangioma, and other signs, this study used MRI STIR imaging combined with CT MPR technology to diagnose acute OVF and combined EDC injury. According to the changes of the morphology and signal of the IVD adjacent to the OVF on the STIR image and the endplate injury on the CT reconstructed image, the EDC injury combined with OVF was divided into grades 0–4. Grade 0: STIR image and CT reconstruction observation revealed that the morphology and signal of the EDC were normal compared with the uninjuried EDC in the distant part, indicating that the EDC was not injuried. Grade 1: STIR image shows diffused or localized high signal in the IVD, and no endplate fracture signs are found in the CT reconstruction image,this represents intradiscal edema or hemorrhage. Grade 2: STIR image shows diffuse or localized high signal in the IVD, the CT reconstruction image reveals a linear fracture of the endplate, with no displacement or collapse of the endplate, and no subendplate sclerosis or subendplate effusion, this represents EDC injury. Grade 3: In addition to grade 2 changes, CT reconstruction images show endplate displacement, collapse, subendplate bone sclerosis, subendplate effusion, and even part of the IVD herniated into the vertebral body. This type of EDC injury are more serious. Grade 4: In addition to grade 2 or 3 changes, complicated with posterior wall fracture (Fig. 1 to Fig. 4).

Intra- and inter-observer agreement assessment of EDC injury

One orthopedic surgeon evaluated images two times to assess intra-observer agreements. To assess inter-observer agreements, two orthopedic surgeons evaluated 50 randomly selected patients (50 vertebrae). Intra- and interobserver agreements were assessed by calculating the Cohen kappa coefficient. A kappa of < 0.00 was interpreted as minimal agreement, 0.00-0.20 as slight agreement, 0.21–0.40 as fair agreement, 0.41–0.60 as moderate agreement, and 0.61–0.80 as substantial agreement. The agreement was regarded as “substantial” when the kappa values were more than 0.61.

Data Analysis

According to fractured level, OVF were divided into thoracic group (T6-T10), thoracolumbar group (T11-L2), and lumbar group (L3-L5). For each group, we compared the incidence and degree of EDC injury. According to the diagnostic criteria recommended by the WHO, the included cases were divided into osteoporosis group ($-3.5 < T$ score ≤ -2.5) and severe osteoporosis group (T score ≤ -3.5), and the incidence and degree of injury of the two groups of patients with EDC injury were compared. Following the Genant[18] semi-quantitative method for grading vertebral fractures, OVF was graded 0–3, and the incidence of different fractures combined with EDC injury and the degree of injury were compared.

Statistical Analysis

Statistical analysis was performed using the commercial software package SPSS 19.0 (SPSS, Chicago, Illinois, USA). All results for continuous variables are presented as mean ± SD, and those for categorical variables are expressed as n. The Kruskal-Wallis H rank-sum test was used to compare the difference in the incidence and degree of injury between different fracture sites and different fracture levels combined with EDC injury. The Wilcoxon rank-sum test was used to compare the difference in the incidence and degree of injury between osteoporosis patients and severe osteoporosis patients with EDC injury. $P < 0.01$ was taken to indicate statistically significant differences.

Results

From August 2017 to August 2020, a total of 1249 cases of OVF were diagnosed in the orthopedics department of the Affiliated Hospital of Southwest Medical University. Of these, 479 cases were in line with our inclusion; 321 cases were combined with EDC injury, with 308 cases involving the cranial disc and 13 cases the caudal disc. (Due to the low incidence of caudal disc injury, this study did not include it in the scope of observation.) There were 120 male and 359 female patients, aged 57–92 (71.8 ± 6.9) years old, with 108 cases of same-level fall injuries, 96 cases of fall from a height, 133 cases of waist sprain, and 142 cases of no clear history of trauma. Intra- and inter-observer agreements for the assessment of disc injuries were both “substantial,” with kappa values of 0.86 and 0.82, respectively.

In the thoracic group (T6-T10), there were 143 cases of OVF combined with EDC injury as follows: 78 cases of grade 0, 27 cases of grade 1, 18 cases of grade 2, 13 cases of grade 3, and 7 cases of grade 4. In the thoracolumbar group (T11-L2), there were 218 cases of OVF combined with EDC injury as follows: 34 cases of grade 0, 19 cases of grade 1, 37 cases of grade 2, 53 cases of grade 3, and 75 cases of grade 4. In the lumbar group (L3-L5), there were 105 cases of OVF combined with EDC injury as follows: 46 cases of grade 0, 20 cases of grade 1, 17 cases of grade 2, 12 cases of grade 3, and 10 cases of grade 4. The incidence of OVF combined with EDC injury was highest in the thoracolumbar group, and the degree of damage was severe. Compared with the thoracic group and the lumbar group, the differences were statistically significant ($P < 0.01$) (Table 1).

Table 1
Comparison of the incidence and degree of injury of OVF combined with EDC injury in different fracture levels.

	Grade [cases(%)]				
Fracture level(n)	0	1	2	3	4
Thoracic group(143)	78(54.5)	27(18.9)	18(12.6)	13(9.1)	7(4.9)
Thoracolumbar group(218)	34(15.6)	19(8.7)	37(17.0)	53(24.3)	75(34.4)
Lumbar group(105)	46(43.8)	20(19.1)	17(16.2)	12(11.4)	10(9.5)
χ^2	107.427				
P	0.000				

There were 246 cases in which the bone mineral density (BMD) T score was below − 3.5, with EDC injury grades as follows: 49 cases of grade 0, 23 cases of grade 1, 43 cases of grade 2, 57 cases of grade 3, and 74 cases of grade 4. There were 220 cases in which the BMD T score was between − 3.5 and − 2.5, with EDC injury grades as follows: 109 cases of grade 0, 43 cases of grade 1, 29 cases of grade 2, 21 cases of grade 3, and 18 cases of grade 4. The incidence of severe osteoporosis combined with EDC injury is higher, and the degree of injury is severe. Compared with the osteoporosis group, the differences were statistically significant ($P < 0.01$) (Table 2).

Table 2
Comparison of the incidence and degree of injury of OVF combined with EDC injury in patients with osteoporosis and severe osteoporosis.

	Grade [cases(%)]				
The T score of BMD	0	1	2	3	4
-3.5 < T score≤-2.5	109(49.5)	43(19.5)	29(13.2)	21(9.5)	18(8.3)
T score≤-3.5	49(19.9)	23(9.3)	43(17.5)	57(23.2)	74(30.1)
Z	-8.733				
P	0.000				

Using the Genant semi-quantitative method, there were 101 grade 0 OVF cases, with the distribution of EDC injuries being 74 grade 0, 4 grade 1, 4 grade 2, 10 grade 3, and 9 grade 4. Among the 83 grade 1 OVF cases, the EDC injury distribution was 30 grade 0, 15 grade 1, 11 grade 2, 13 grade 3, and 14 grade 4. Among the 132 grade 2 OVF cases, the EDC injury distribution was 33 grade 0, 36 grade 1, 20 grade 2, 21 grade 3, and 22 grade 4. Finally, among the 150 grade 3 OVF cases, the EDC injury distribution was 21 grade 0, 11 grade 1, 37 grade 2, 34 grade 3, and 47 grade 4. The more severe the OVF injury, the higher the incidence of combined EDC injury, and the greater the severity of the EDC injury. There were statistically significant differences between groups of different fracture degrees ($P < 0.01$) (Table 3).

Table 3
Comparison of the incidence and severity of EDC injury associated with different degrees of vertebral body fractures.

	Grade [cases(%)]				
The severity of vertebral fracture(n)	0	1	2	3	4
Genant Grade 0 (101)	74(73.3)	4(4.0)	4(4.0)	10(9.9)	9(8.8)
Genant Grade 1 (83)	30(36.1)	15(18.1)	11(13.3)	13(15.7)	14(16.8)
Genant Grade 2 (132)	33(25.0)	36(27.3)	20(15.2)	21(15.9)	22(16.6)
Genant Grade 3 (150)	21(14.0)	11(7.3)	37(24.7)	34(22.7)	47(31.3)
c^2	80.796				
P	0.000				

Discussion

PKP surgical treatment of OVF can immediately relieve the patient's pain, restore the height of the vertebral body, and correct the kyphosis; moreover, the operation time is short, the trauma is minor, and the surgical skills are easy to master, so it has gradually become one of the main methods for OVF treatment[3–8]. However, some patients still have local pain after the operation, complicated by adjacent vertebral fractures, secondary local instability, and even local kyphotic deformity[10–11]. Takahashi S et al. [19] reported that the above-mentioned complications were mainly caused by PKP surgery focused solely on the fractured vertebral body itself, ignoring the treatment of the adjacent EDC injury. As the degeneration of the injured IVD accelerates, the local stability of the fracture is lost, and the uneven axial load distribution will eventually result in local chronic pain, adjacent vertebral fractures, and even progressive loss of correction in severe cases. Lin et al. [20] have shown that 60% of the instability caused by spinal fractures arises from the EDC. Boeree et al.[21] proposed that the integrity of the IVD above the fractured vertebral body is an important factor in maintaining stability. Although the EDC is an important structure for maintaining the integrity of the spine, dispersing axial load, and absorbing shock, there are very few studies of OVF combined with EDC injury. The classification of IVD injury with normal bone mass fracture and IVD injury proposed by Sander et al. is not suitable for patients with osteoporosis. Ortiz et al.[22] reported for the first time the incidence of OVF patients having IVD injury and its impact on the treatment effect, but they did not classify and observe the degree of IVD injury associated with OVF. Tatsuhiko et al. conducted research mainly on whether the healing of OVF in patients with IVD injuries depended on the Sander et al. classification. At present, there is no relevant research on the classification of OVF combined with EDC injury. This study used MRI and CT to observe OVF with combined EDC injury for the first time. The purpose is to establish a new classification to improve communication between spine surgeons and radiologists and facilitate clinical decision making in spine surgery.

Conventional wisdom holds that the trauma that causes OVF is usually minor, and it is not easy to damage adjacent structures. However, the rate of OVF combined with IVD damage in this study is as high as 67.0%, which is slightly higher than the results of Ortiz and Tatsuhiko. This may be because this study used the highly sensitive STIR sequence to observe changes of the IVD signal, in combination with CT MPR technology, to improve the diagnosis rate of EDC injury. This study found that the combined EDC injury in OVF patients occurred mainly on the cranial side of the fractured vertebral body (64.3%), and less often involved the EDC on both sides of the fractured vertebral body. This may be due to the minor trauma of OVF injury.

This study found that the incidence of EDC injury was higher, and the degree of injury more severe, for patients in the thoracolumbar group than for those in the thoracic and lumbar groups. The main reasons are as follows: (1) the thoracolumbar is located at the junction of thoracic kyphosis and lumbar lordosis; (2) the thoracolumbar is in the stress junction area between the thoracic cage and the lumbar spine; and (3) the thoracolumbar vertebral body does not have the thoracic cage and strong psoas major muscle protection. Once it is traumatized, the thoracolumbar vertebral body is prone to fractures, and the degree of fracture and the combined degree of EDC damage are often very serious. In some elderly patients with secondary osteoporosis, the loss of bone mineral and bone matrix and bone microstructure degeneration are very obvious. Severe osteoporosis often occurs, the fragility of the vertebral body is significantly increased, and minor trauma can cause vertebral body fracture. This study found that OVF in patients with severe osteoporosis was associated with a higher incidence and severity of EDC injury, which may be principally because patients with severe osteoporosis have greater bone loss, and consequently their vertebral bodies become more fragile. Once the vertebral body fractures, it is easier to spread to the vertebral body endplates, resulting in IVD damage. The IVD and the adjacent vertebral body are the integral movement unit. Whether it acts on the IVD or the vertebral body, destructive force can easily be transmitted to the adjacent structure and cause damage. Employing the Genant semi-quantitative method, this study found that the degree of vertebral body fracture is almost the same as the degree of EDC injury. The more serious the degree of vertebral body fracture, the higher the incidence of combined EDC injury and the more severe the degree of EDC injury.

PKP surgery is used to treat OVF, which can quickly relieve acute pain and obtain satisfactory clinical effects. However, secondary degeneration of the injured intervertebral disc, local instability, adjacent vertebral body fractures, and secondary kyphosis will significantly affect the patient, and may even require surgical treatment again. Such patients are often elderly, often with multiple organ dysfunction, and it may be difficult for them to tolerate reoperation. Therefore, the first treatment for OVF and the combined injury of the EDC is very important. In OVF patients, if the EDC injury classification is grade 0 or 1, we recommend that the treatment be selected based on the degree of vertebral fracture, without special treatment of the injured IVD. If the EDC injury is grade 2, we recommend PKP to treat OVF as the first choice. In addition, intraoperative bone cement subendplate distribution should be achieved as much as possible to prevent the damaged endplate from collapsing. If the EDC injury is classified as grade 3 or 4, according to the patient's tolerance to surgery, discectomy, reduction of fractured vertebral body and injuried endplate, intervertebral bone grafting, and internal fixation are preferred for the patients. If the patient cannot withstand general anesthesia, percutaneous vertebral body-intervertebral disc cementoplasty may also be one of the effective treatment methods for such patients[23]. However, when injecting bone cement, it is necessary to prevent the bone cement from leaking into the spinal canal through the fracture line of the posterior wall of the vertebral body. Certainly, the above treatment methods need to be combined with standard anti-osteoporosis treatment, brace protection, and enhancement of core muscle strength. As one of the main structures of the spine motor unit, the EDC plays a vital role in maintaining the stability and integrity of the spine, and in protecting the nerves and dispersing the axial load. Especially for OVF patients, there may only be one chance for surgery. Clinicians can carefully screen OVF combined with EDC injuries according to the classification criteria formulated herein and choose individual treatment methods to maximize the therapeutic effect of OVF.

This study is a single-center retrospective study. It deals only with imaging observations. The reliability of guiding the choice of treatment will require long-term clinical observation and follow-up.

Conclusion

The incidence of OVF combined with EDC injury is 67.0%, and the cranial side of the fractured vertebral disc is more likely to be involved. Combining MRI and CT to observe the morphology and signal changes of adjacent EDC in patients with OVF, the combination of OVF and EDC injury can be divided into five grades from 0 to 4, with incidence rates of 33.9%, 14.2%, 15.5%, 16.7%, 19.7%, respectively. To patients with OVF, severe osteoporosis, and severe fractures in the thoracolumbar segments often have more severe EDC jnjury. Further studies must be conducted to verify clinical relevance.

Abbreviations

BMD,bone mineral density; CT,Computed tomography; EDC,endplate-disc complex; IVD,intervertebral disc; MPR,multiplanar reconstruction; MRI,magnetic resonance imaging; OVF,osteoporotic vertebral fracture; PKP,Percutaneous kyphoplasty; STIR,short TI inversion recovery.

Declarations

Ethical approval and consent to participate

The study protocol was approved by the Ethics Committee of the Affiliated Hospital of Southwest Medical University.All patients provided written informed consent prior to their inclusion in this study.

Consent for publication

Not applicable

Availability of data and materials

Data will be available upon request to the first author ZS.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

ZS and WQ conceived the original study and developed the protocol together with WS, Statistical advice was provided by XS and YJ. ZS wrote the manuscript. All authors read and approved the final manuscript.

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Figures

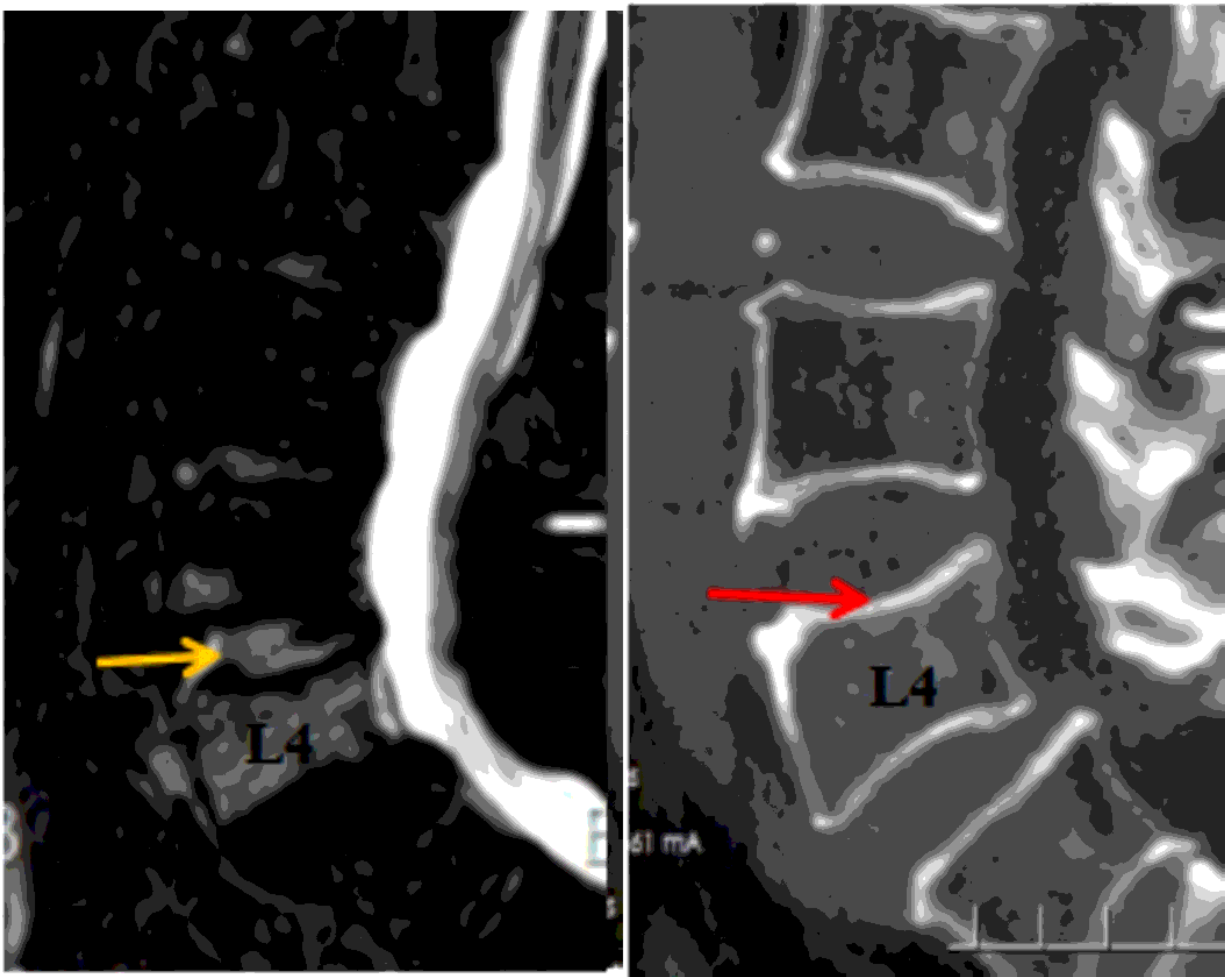

Figure 1

68-year-old man with OVF at level L4. Panel A is an MRI STIR image. The yellow arrow indicates a diffuse high signal in the IVD on the cranial side of the fractured vertebral body whose signal intensity is close to that of cerebrospinal fluid. Panel B is a CT image of the fractured vertebral body. The red arrow indicates that the upper endplate of the L4 vertebral body is intact. This is a grade 1 IVD injury as delineated in this study.

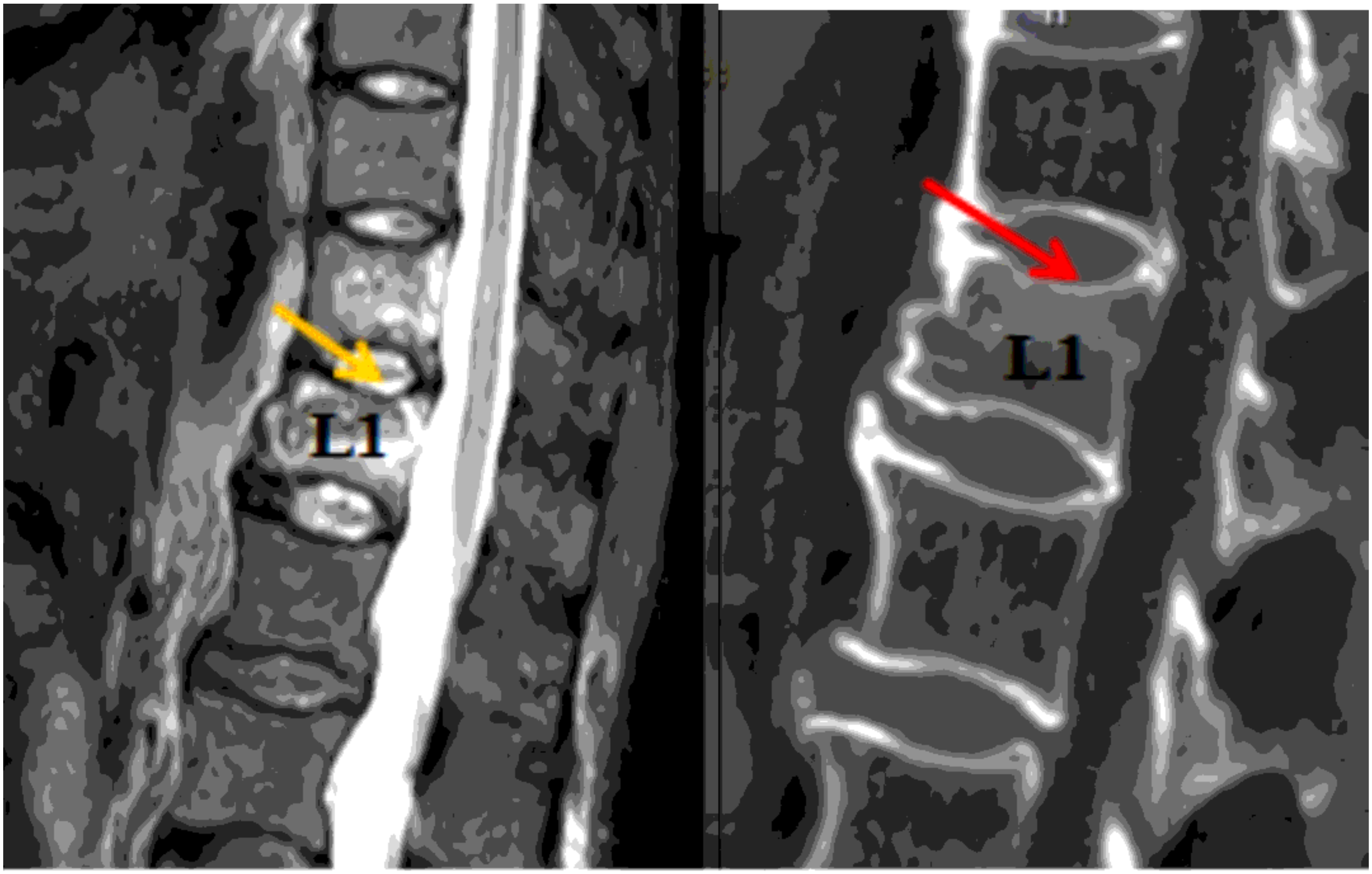

Figure 2

73-year-old woman with OVF at level L1. Panel A is an MRI STIR image. The yellow arrow indicates a diffuse high signal in the IVD on the cranial of the fractured vertebral body. Panel B is a CT image of the fractured vertebral body. The red arrow indicates a linear fracture of the upper endplate of the L1 vertebral body, but there is no sign of displacement or collapse of the endplate. This is a grade 2 EDC injury as delineated in this study.

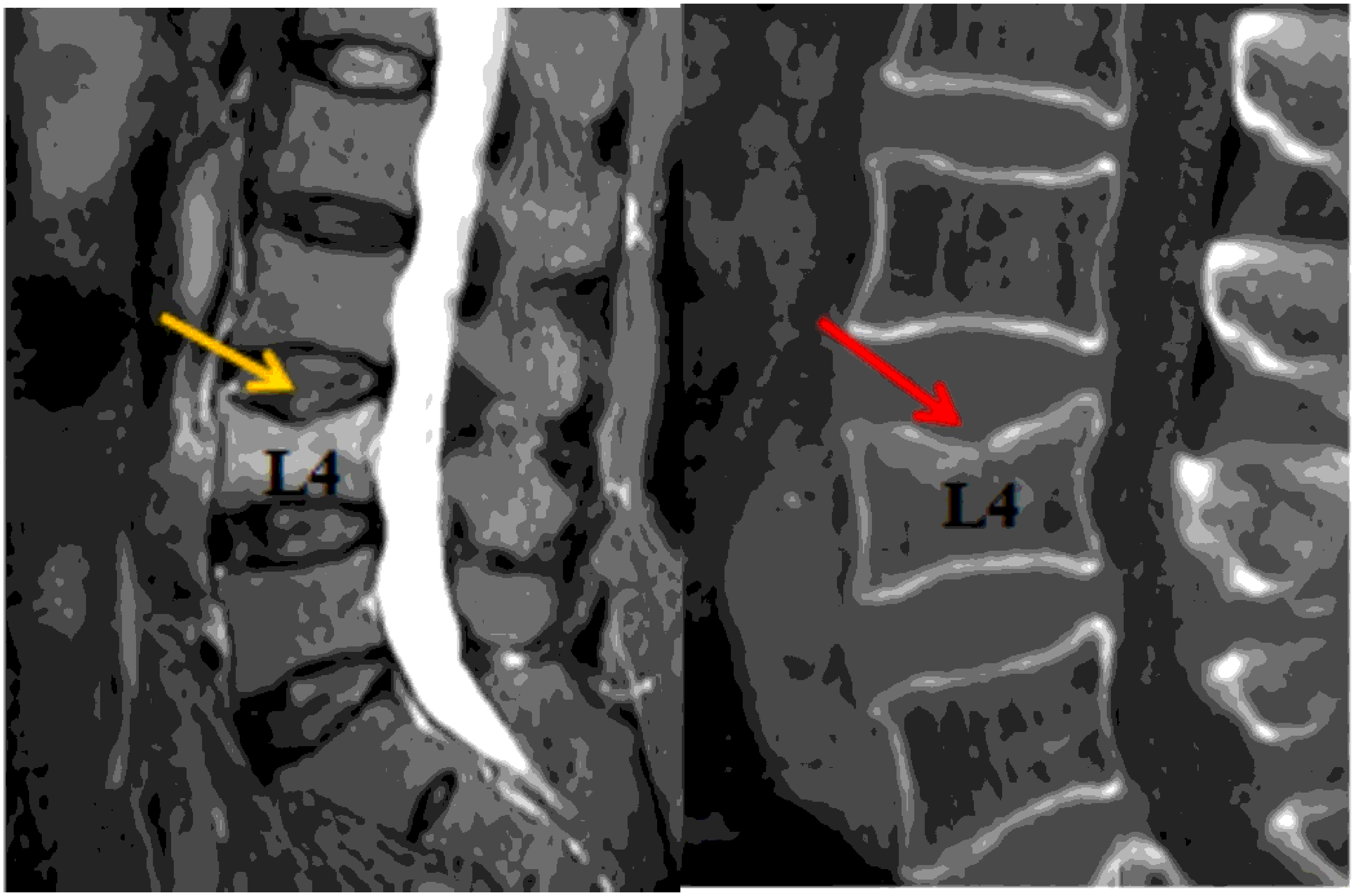

Figure 3

76-year-old woman with OVF at level L4. Panel A is an MRI STIR image. The yellow arrow indicates a diffuse high signal in the OVF on the cranial of the fractured vertebral body and a fracture of the upper endplate of the vertebral body. Panel B is a CT image of the fractured vertebral body. The red arrow indicates a fracture of the upper endplate of the L4 vertebral body. The endplate collapses with signs of bone sclerosis below the endplate. This is a grade 3 EDC injury as delineated in this study.

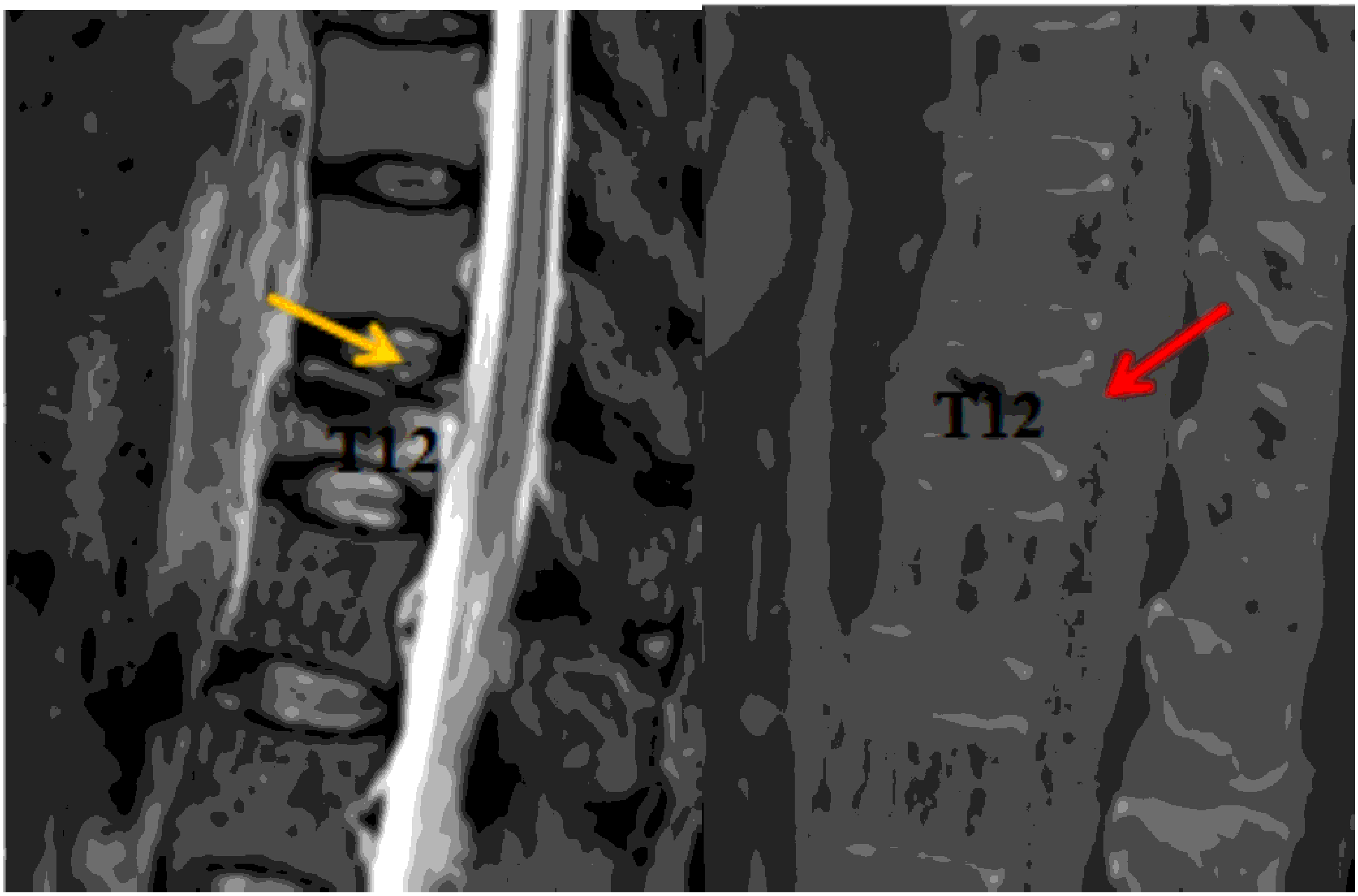

Figure 4

74-year-old woman with OVF at level T12. Panel A is an MRI STIR image. The yellow arrow indicates a diffuse high signal in the IVD on the cranial of the fractured vertebral body and a fracture of the upper endplate of the vertebral body. Figure B is a CT image of the fractured vertebral body. The red arrow indicates that the upper endplate of the T12 vertebral body is fractured, and the endplate collapse is accompanied by a fracture of the posterior vertebral body. This is a grade 4 EDC injury as delineated in this study.