

Correlation Between the Severity of Acute Vertebral Fractures Diagnosed on Computed Tomography and the Presence of Acute Disc Pathology on Magnetic Resonance Imaging

Fatemeh Lotfi^{1*}, Mohammad Khalafi^{2#}, Abolhasan Shakeri¹, Javad Jalili¹, Mohammad Mirza-Aghazadeh-Attari², Esmaeil Gharepapagh¹, Mahsa Karbasi^{1*}, Sahar Rezaei^{1*}

¹Department of Radiology, Tabriz University of Medical Sciences, Tabriz, Iran

²Russell H. Morgan Department of Radiology and Radiological Sciences, Johns Hopkins Medicine, Baltimore, USA

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*Corresponding Authors:

Mahsa Karbasi,
Email: mahsakarbsi@gmail.com
and Sahar Rezaei,
Email: s.rezaei.tums@gmail.com

*These authors contributed
equally to this work

Abstract

Objectives: To evaluate the relationship between computed tomography (CT)-based Vertebral compression fractures (VCFs) severity and intervertebral disc pathology on magnetic resonance imaging (MRI).

Design: A cross-sectional study.

Setting(s): Single-center trauma imaging, Tabriz, Iran.

Participants: A total of 150 consecutive adult patients with acute thoracic or lumbar spine trauma who underwent both CT and MRI examinations.

Outcome measures: VCFs severity graded on CT based on vertebral height loss and fracture morphology; MRI assessment of bone marrow edema extent and intervertebral disc pathology using a semi-quantitative grading system.

Results: Grade 1 VCFs were the most common (52%), followed by grade 2 (40%). Disc abnormalities included edema (22.7%) and herniation (18%), while 56.7% of discs appeared normal. Moreover, bone marrow edema involving one-third to two-thirds of vertebral height was present in nearly half of the cases. In addition, subendplate fractures were the most frequent morphological subtype (41.3%). Furthermore, a VCF grade ≥ 2 predicted MRI-detected disc herniation with a sensitivity of 81.4%, specificity of 59.3%, negative predictive value of 93.5%, and positive predictive value of 30.5%. Ultimately, higher VCF grades were significantly associated with disc herniation and more extensive bone marrow edema.

Conclusions: Overall, higher-grade VCFs on CT are associated with disc herniation and greater marrow edema on MRI in acute spinal trauma. Additionally, CT severity grading may assist in identifying patients who warrant prompt MRI evaluation. However, CT alone should not be used to guide surgical decision-making.

Keywords: Spinal fractures, Vertebral compression fractures, Computed tomography, X-ray, Magnetic resonance imaging, Intervertebral disc, Spinal injuries

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Introduction

Vertebral compression fractures (VCFs) represent a common subtype of vertebral injuries and may occur in various clinical contexts, including osteoporosis, malignancy, and acute trauma.¹ Although osteoporotic VCFs are highly prevalent in elderly populations, particularly women, the incidence of traumatic VCFs is notable among younger individuals exposed to high-energy mechanisms (e.g., motor vehicle collisions or falls from height).² In addition, acute traumatic VCFs in

adults frequently involve the mechanical disruption of the vertebral body and adjacent intervertebral discs.

Intervertebral disc injury is a serious consequence of axial spinal trauma. Post-traumatic disc damage may manifest as edema, hemorrhage, herniation, or early height loss, each of which can influence pain severity, neurological symptoms, and long-term degenerative changes.^{3,4} Therefore, early detection of disc involvement is clinically relevant, especially in young patients with substantial functional demands.



Computed tomography (CT) is the first-line imaging modality for evaluating acute spinal trauma due to its rapid acquisition, high spatial resolution, and superior ability to characterize osseous morphology. Fracture severity, often quantified by vertebral height loss and morphological classification, may provide indirect clues regarding associated soft-tissue injuries. On the other hand, magnetic resonance imaging (MRI) remains the gold standard for assessing bone marrow edema, disc pathology, and ligamentous structures.⁵⁻⁷ Nonetheless, MRI availability is limited or delayed in many trauma centers, prompting interest in whether CT findings can predict MRI-detected disc abnormalities.

Understanding the relationship between CT-based VCF grading and MRI-defined disc pathology may assist clinicians in stratifying risks, guiding further imaging, and making urgent management decisions, especially when MRI is not immediately accessible. Accordingly, this study aims to evaluate the correlation between the severity of acute traumatic VCFs on CT and intervertebral disc changes on MRI in adult patients presenting with acute spine trauma. It is noteworthy that pathological fractures related to malignancy or metabolic bone disease have been excluded to ensure a homogeneous traumatic cohort.

Methods

Study Design

This cross-sectional study was conducted at a tertiary trauma center between February 2021 and May 2021. Based on the previously reported prevalence estimates of acute traumatic VCFs and prior similar studies, a target sample size of 150 patients was determined to provide adequate precision for correlation analyses. In addition, a census (consecutive) sampling approach was used, implying that all adult patients presenting with acute spinal trauma and confirmed VCFs on both CT and MRI during the study period were enrolled in this study. Considering that the study was based on a predefined temporal window, a formal screening log was not maintained, and the exact number of initially screened or excluded patients could not be retrieved retrospectively. However, the final cohort of 150 individuals represents the complete population of patients who met all eligibility criteria during this interval. It is worth mentioning that the study received ethics approval from the institutional review board, and written informed consent was also obtained from all participants. The inclusion criteria were age ≥ 18 years, acute spinal trauma, and CT-confirmed and MRI-confirmed VCFs. On the other hand, the exclusion criteria included pathological vertebral fractures and pre-existing non-traumatic VCFs.

Image Acquisition

All patients underwent CT imaging of the thoracic or lumbar spine using a Philips multislice single-energy CT scanner (Canon Medical Systems). Moreover, the

examinations were performed with a tube voltage of 120 kVp and a slice thickness of 2 mm. Images were reconstructed with a high-resolution bone algorithm (window width 2000; level 500) and reviewed in axial and sagittal reformations in order to allow optimal assessment of vertebral morphology. In addition, an MRI was conducted using a 1.5-T system (MAGNETOM Avanto or MAGNETOM Symphony Vision, Siemens Healthineers). The protocol included sagittal T1-weighted spin-echo, sagittal T2-weighted fast spin-echo, sagittal short tau inversion recovery, and axial T2-weighted sequences. It should be noted that these sequences were selected to enable detailed evaluation of bone marrow edema, disc signal abnormalities, and the presence of traumatic herniations.

The images were independently interpreted by two radiologists with over five years of experience in spine imaging. In cases of disagreement, a third radiologist reviewed the images to reach a consensus. Additionally, disc abnormalities were classified using a semi-quantitative MRI grading system ranging from 0 to 4. Grades 0 and 1 represented normal disc signal intensity and edema without disc contour abnormality, respectively. In addition, grades 2 and 3 corresponded to intradiscal hemorrhage or focal signal alteration and traumatic herniation, respectively. Further, grade 4 indicated traumatic disc height loss or collapse. This structured grading approach has been applied in prior studies on acute thoracolumbar trauma, demonstrating good diagnostic performance for distinguishing traumatic disc injuries and correlating MRI findings with clinical severity. These previously published grading systems support the reliability and applicability of the method used in the present study.⁸ It should be mentioned that all intervertebral discs adjacent to the fractured vertebrae were included in the analysis, regardless of whether they appeared normal or abnormal. This approach ensured a comprehensive assessment of disc status across the full spectrum of MRI findings. Only discs adjacent to the fractured vertebral level were evaluated, and degenerative changes were not classified as traumatic; they were distinguished using ancillary findings, such as osteophytes or Modic-type endplate changes. Furthermore, bone marrow edema was categorized as involving less than one-third, one-third to two-thirds, or more than two-thirds of the vertebral body height. Formal inter-observer agreement statistics (e.g., Cohen's kappa) were not prospectively recorded. Discrepancies between the two primary readers were resolved by consensus with a third radiologist.

VCFs were graded on CT using the Genant classification, which categorizes vertebral height loss into grades 0 through 3. In addition, fracture morphology was assessed and classified as anterior, central, burst, subendplate, or subendplate–anterior (Figure 1). Finally, endplate involvement was recorded as present or absent based on the extension of fracture lines. This multiparametric

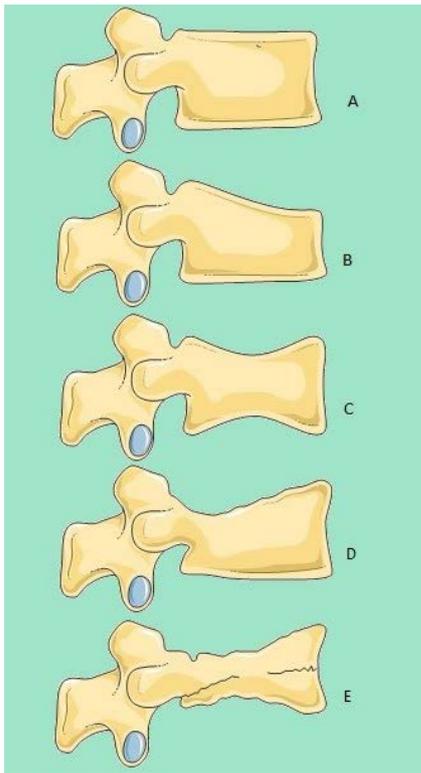


Figure 1. Fracture Type Classification Based on Fracture Shape: (A) Normal Vertebra, (B) Anterior Fracture, (C) Mid-Fracture, (D) Posterior Fracture, and (E) Burst Fracture

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CT assessment allowed detailed correlation with MRI findings.

Statistical Analysis

The obtained data were statistically analyzed using SPSS, version 23.0 (IBM Corporation, Armonk, New York). Quantitative and categorical variables were presented as means \pm standard deviations, as well as frequencies and percentages, respectively. Pearson or Spearman correlation coefficients were calculated to assess the relationship between CT-based fracture severity and MRI-based disc or bone marrow abnormalities, depending on data distribution. A *P*-value of less than 0.05 was considered statistically significant.

Results

Overall, 150 patients with acute thoracic or lumbar VCFs were included in this study (Table 1). Based on CT grading, grade 1 fractures were the most common (52%), followed by grade 2 (40%) and grade 3 (8%) fractures. The distribution of fracture morphologies, including anterior, central, subendplate, subendplate–anterior, and burst types, is illustrated in Figure 1, with subendplate fractures being the most frequent pattern (41.3%), followed by burst fractures (29.3%).

The MRI evaluation of the intervertebral discs adjacent to the fractured vertebrae showed that 56.7% were normal, while disc edema (22.7%) and disc herniation (18%) were

Table 1. Overall Frequency of Imaging Findings

Variables	Frequency (%)	Classification
Compression fractures grading (CT)	78 (52)	1 (<25%)
	60 (40)	2 (25-40%)
	12 (8)	3 (40%>)
Disc changes (MRI)	85 (56.7)	0 (normal)
	34 (22.7)	1 (edema)
	1 (0.7)	2 (hemorrhage)
	27 (18)	3 (hernia)
Bone marrow edema (MRI)	3 (2)	4 (decreased height)
	42 (28)	Lower than 1/3
	75 (50)	Between 1/3 and 2/3
	35 (22)	Higher than 2/3
Fracture morphology CT	4 (2.7)	Anterior
	6 (4)	Central
	44 (29.3)	Burst
	62 (41.3)	Subendplate
	34 (22.7)	Subendplate-anterior
End plate involvement	95 (63.3)	

Note. MRI: Magnetic resonance imaging; CT: Computed tomography.

the predominant abnormalities (Table 1). Representative MRI appearances of disc edema and herniation are illustrated in Figure 2. Similarly, bone marrow edema was common, with the involvement of one-third to two-thirds of vertebral height in 50% of cases and more extensive edema (>two-thirds) in 22% (Table 1, Figure 3).

A significant positive correlation was found between CT-based VCF grade and MRI-confirmed disc herniation ($r=0.323$, $P=0.001$, Table 2). In addition, a fracture grade ≥ 2 predicted disc herniation with a sensitivity of 81.4%, specificity of 59.3%, negative predictive value (NPV) of 93.5%, and positive predictive value (PPV) of 30.5% (Table 2). The relationship between CT grade and disc herniation is depicted in Figure 4.

Moreover, fracture morphology on CT demonstrated a noticeable association with disc herniation ($r=0.249$, $P=0.022$), while other disc changes, such as edema and hemorrhage, were not significantly correlated (Table 3). However, endplate involvement was considerably related to disc herniation ($r=-0.184$, $P=0.024$) and disc edema ($r=-0.183$, $P=0.025$) while showing no significant association with other disc abnormalities (Table 4).

A strong correlation was observed between CT-based VCF grade and MRI-assessed bone marrow edema severity ($r=0.654$, $P<0.001$, Table 5).

Discussion

The results of this study on 150 patients with acute traumatic VCFs revealed that higher VCF grades on CT were significantly associated with an increased likelihood of disc herniation and with more severe bone marrow edema on MRI. Moreover, a CT-based fracture grade ≥ 2 represented high sensitivity and a strong NPV for

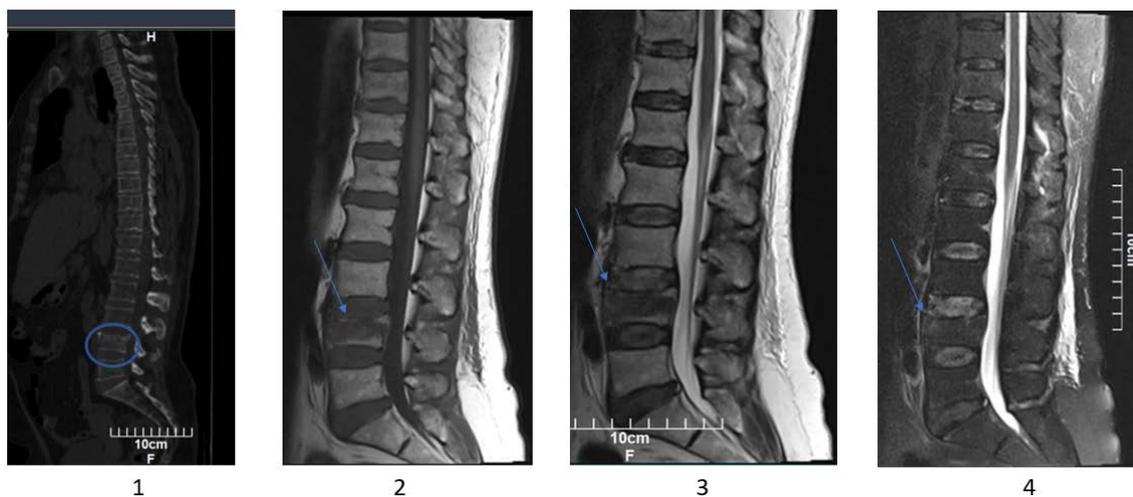


Figure 2. Sagittal Reconstructed CT Scan Images (a), Sagittal T1 (b), T2 (c), and FAT SAT (d) Images Showing Grade 1 Compression Fracture of L4 Vertebral Body With Subplate-Anterior Morphology and Grade 1 Bone Marrow Edema, Disc Injury Grade: 0
 Note. CT: Computed tomography



Figure 3. Sagittal Reconstructed CT Scan Images (a), Sagittal T1 (b), T2 (c), and FAT SAT (d) Images Displaying Grade 2 Compression Fracture of L1 Vertebral Body With Grade 2 Bone Marrow Edema, Sub-Endplate-Anterior Morphology-Grade of Disc Injury Cranial and Caudal: 0
 Note. CT: Computed tomography. Mild retropulsion has caused anterior indentation of the thecal sac at the same level (arrow)

Table 2. The Correlation of Vertebral Compression Fracture Grading Based on CT With Intervertebral Disc Status

Disc Changes (MRI)	Compression Fractures Grading (CT)			Total	P-Value
	1 (<25%)	2 (25-40%)	3 (40% >)		
Edema	16 (47.1)	15 (44.1)	3 (8.8)	34 (22.7)	0.552 r=0.049
Hemorrhage	0	0	1 (14.3)	1 (0.7)	0.023 r=0.185
Hernia	5 (18.5)	17 (63)	5 (18.5)	27 (18)	0.001 r=0.323
Decreased height	1 (33/3)	2 (66/7)	0	3 (2)	0.772 r=0.024

Note. MRI: Magnetic resonance imaging; CT: Computed tomography

identifying disc herniation. Likewise, burst-type fractures showed a particularly strong relationship with MRI-detected herniation. Furthermore, CT severity grading closely correlated with the degree of bone marrow edema on MRI. These results suggest that the CT-based assessment of fracture severity may provide meaningful predictive information regarding associated soft-tissue

injuries, especially in acute trauma scenarios where MRI may not be immediately available.

Consistent with our findings, disc herniation displayed a clear positive association with increasing VCF grade on CT, and grade ≥ 2 fractures demonstrated high sensitivity (81.4%) and an excellent NPV (93.5%) for predicting MRI-confirmed herniation. Although specificity and PPV

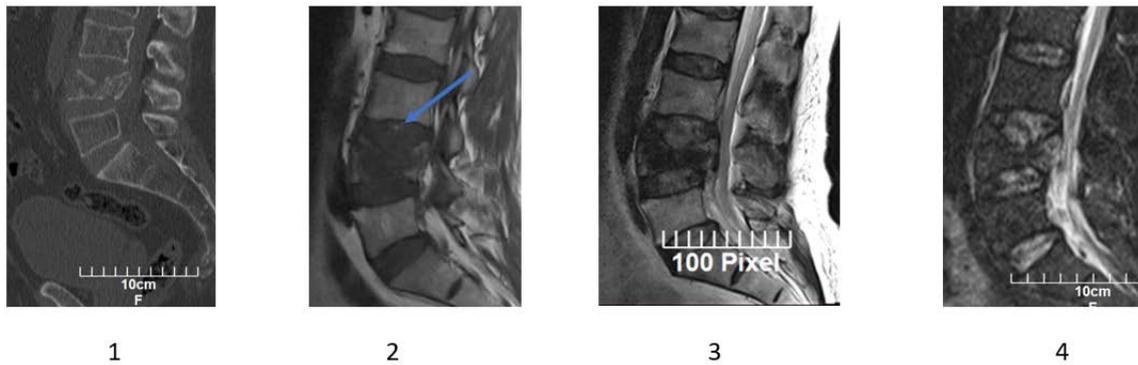


Figure 4. Sagittal Reconstructed CT Scan Images (a), Sagittal T1 (b), T2 (c), and FAT SAT (d) Images Depicting Grade 2 Compression Fracture of L4 Vertebra With Grade 2 Bone Marrow Edema and Diffuse Morphology
 Note. MRI: Magnetic resonance imaging; CT: Computed tomography. Disc injury grade: Cranial disc (grade 3) and caudal disc (grade 0). A small high T1 signal intensity focus is present at the cranial disc (arrow), indicating hemorrhage

Table 3. Results Related to the Relationship Between CT-Based Vertebral Fracture Morphology and Intervertebral Disc Status

Fracture Morphology	Disc Changes (MRI)			
	Decreased Height	Hernia	Hemorrhage	Edema
Anterior	(2.9) 1	0	(3.7) 1	0
Central	(5.9) 2	0	0	0
Burst	(44.1) 15	0	(51.9) 14	(66.7) 2
Subendplate	(23.5) 8	(100) 1	(18.5) 5	(33.3) 1
Subendplate-anterior	(23.5) 8	0	(25.9) 7	0
<i>P</i> -value	0.190	0.809	0.022	0.412
	0.108- <i>r</i> =	<i>r</i> =0.020	<i>r</i> =0.249	0.067- <i>r</i> =

Note. MRI: Magnetic resonance imaging; CT: Computed tomography.

Table 4. Correlation of Vertebral Endplate Involvement Based on CT With Intervertebral Disc Status

End Plate Involvement	Disc Changes (MRI)			
	Edema	Hemorrhage	Hernia	Decreased Height
Positive	16 (47.1)	0	12 (44.4)	1 (33.3)
Negative	18 (52.9)	1 (100)	15 (55.6)	2 (66.7)
<i>P</i> -value	0.025	0.449	0.024	0.279
	<i>r</i> =-0.183	<i>r</i> =0.062	<i>r</i> =-0.184	<i>r</i> =-0.089

Note. MRI: Magnetic resonance imaging; CT: Computed tomography

Table 5. Correlation of Vertebral Compression Fracture Grading Based on CT With Bone Marrow Edema Grading Based on MRI

Bone Marrow Edema Grading	Compression Fracture Grading (CT)			Total
	1 (< %25)	2 (%25-%40)	3 (%40>)	
Lower than 1/3	40 (51.3)	2 (3.3)	0	42 (28)
Between 1/3 and 2/3	36 (46.2)	37 (61.7)	2 (16.7)	75 (50)
Higher than 2/3	2 (2.6)	21 (35)	10 (83.3)	33 (22)
Total	78 (52)	60 (40)	12 (8)	150 (100)

Note. MRI: Magnetic resonance imaging; CT: Computed tomography.

were modest, these results suggest that low-grade fractures (grade 0–1) are unlikely to be accompanied by traumatic herniation, whereas higher-grade fractures warrant closer evaluation. Despite the strong sensitivity and NPV, the relatively low PPV ($\approx 30\%$) indicates that a considerable proportion of patients with CT grade ≥ 2 fractures do not exhibit traumatic disc herniation on MRI. This finding is expected, given the overall lower prevalence of herniation compared with vertebral fractures, reflecting the known

statistical behavior of PPV in low-prevalence conditions. Clinically, this issue implies that while CT is useful for identifying patients who require further evaluation, it cannot confirm disc herniation with sufficient accuracy to guide operative planning without MRI correlation. Additionally, burst-type fractures illustrated a notable correlation with disc herniation, reinforcing previous biomechanical observations that greater axial force and vertebral body disruption increase disc injury risk.⁷

According to recent studies, MRI may alter thoracolumbar fracture classification or influence operative decision-making in a relevant subset of patients, particularly when soft-tissue or posterior ligamentous complex injuries are suspected.^{9,10} Another study evaluating posterior ligamentous complex integrity has demonstrated that specific CT features correlate with MRI-confirmed ligamentous disruption in burst fractures, supporting the predictive value of CT beyond bony morphology alone.¹¹ Furthermore, post-traumatic disc pathology, including fracture-associated intervertebral disc vacuum phenomenon, has been linked to fracture severity and mechanical instability, reinforcing the biomechanical continuum between vertebral injury and adjacent disc damage.¹² These contemporary findings provide a modern framework for interpreting CT–MRI relationships in thoracolumbar trauma and align with the correlations found in our study.

Likewise, the observed correlation between fracture severity and bone marrow edema supports earlier reports, indicating that greater vertebral height loss and endplate disruption are associated with more extensive marrow involvement.⁸ Although several studies have shown that dual-energy CT (DECT) can detect bone marrow edema with high diagnostic accuracy,^{13–15} our study relied on conventional CT alone. Despite this limitation, CT grade strongly correlated with MRI-detected edema, highlighting the value of CT as an initial triage modality in acute spine trauma.

Overall, our data indicated that CT-based assessment of VCF severity meaningfully correlates with disc pathology and bone marrow edema on MRI. However, given the relatively low PPV of CT for predicting disc herniation, CT findings should not be used as a stand-alone determinant for surgical decision-making. Instead, CT may serve as a practical tool for identifying patients at higher risk of disc injury who would benefit from timely MRI evaluation, particularly in trauma settings where MRI access is limited. Future research incorporating advanced CT techniques (e.g., DECT) may further improve the ability to characterize soft-tissue changes associated with vertebral fractures.¹⁶

This study had several limitations. First, it was conducted at a single tertiary trauma center, which may limit the generalizability of the findings to broader clinical settings. In addition, the cross-sectional design focused solely on initial imaging, without long-term clinical or radiological follow-up to evaluate the progression of disc pathology or functional outcomes. Furthermore, bone mineral density was not assessed, and therefore, the potential influence of underlying osteoporosis could not be evaluated. Moreover, although conventional CT provided reliable fracture characterization, it is less sensitive than advanced modalities, such as DECT, for detecting bone marrow edema and subtle soft-tissue changes. Additionally, no formal a priori sample size calculation was performed, and the study relied on a consecutive sample of eligible

patients during the defined time period, which may affect statistical power for subgroup analyses. Finally, although images were interpreted by experienced radiologists, interobserver agreement metrics were not formally quantified, thereby limiting the ability to assess reader reliability.

Conclusions

Based on our findings, higher CT-based VCF grades were significantly associated with MRI-detected disc herniation and with greater degrees of bone marrow edema in patients with acute spinal trauma. These associations suggest that CT severity grading may provide useful early predictive information about accompanying soft-tissue injuries, particularly in settings where MRI is not immediately accessible. However, given the modest specificity and PPV of CT for disc herniation, CT findings alone should not be used as a definitive indication for surgical fusion. In other words, CT may assist in identifying patients who warrant prompt MRI evaluation and closer clinical assessment. Accordingly, multicenter studies including advanced imaging modalities (e.g., DECT), in conjunction with MRI, may help further clarify the diagnostic and prognostic value of CT-based fracture grading.

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Authors' Contributions

Conceptualization: Fatemeh Lotfi.

Data curation: Fatemeh Lotfi, Mohammad Mirza-Aghazadeh-Attari.

Formal analysis: Mohammad Khalafi.

Investigation: Fatemeh Lotfi.

Methodology: Fatemeh Lotfi, Abolhasan Shakeri.

Project administration: Abolhasan Shakeri.

Supervision: Abolhasan Shakeri, Mahsa Karbasi.

Validation: Esmail Gharepapagh, Sahar Rezaei.

Visualization: Mohammad Khalafi, Javad Jalili, Mahsa Karbasi, Sahar Rezaei.

Writing—original draft: Mohammad Khalafi.

Writing—review & editing: Fatemeh Lotfi, Abolhasan Shakeri, Javad Jalili, Mohammad Mirza-Aghazadeh-Attari, Esmail Gharepapagh, Mahsa Karbasi, Sahar Rezaei.

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Data availability statement

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

Ethical approval and Consent to publication

This study was approved by the Institutional Ethics Committee of Tabriz University of Medical Sciences, Tabriz, Iran (approval code IR.TBZMED.REC.1400.255). It should be noted that all procedures were performed in accordance with the ethical standards of the institutional and national research committees, as well as the 1964 Helsinki Declaration and its later amendments.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Intelligence Use Disclosure

During the preparation of this work, the authors used ChatGPT (OpenAI) to assist with language editing and text clarity improvement. It is worth noting that the authors reviewed and edited the content as needed after using this tool, and they take full responsibility for the content of the published article.

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