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Radiology

MAGNETIC RESONANCE IMAGING IN THE ASSESSMENT OF VERTEBRAL COMPRESSION FRACTURES

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ABSTRACT **Background:** Vertebral compression fractures (VCFs) are among the most common spinal injuries, occurring due to trauma, osteoporosis, or pathological conditions such as malignancy. Accurate assessment is essential for evaluating spinal stability, guiding treatment, and predicting neurological recovery. Magnetic Resonance Imaging (MRI) offers superior soft tissue contrast, enabling detailed evaluation of vertebral morphology, marrow changes, spinal cord, ligaments, and associated soft tissue abnormalities. **Aim:** To assess the role of MRI in evaluating vertebral compression fractures in terms of their type, extent, and associated spinal and soft tissue injuries. **Methodology:** A prospective observational study was conducted on 63 patients with clinically suspected or confirmed vertebral compression fractures at the Department of Radiology. MRI was performed using a 1.5 Tesla Philips Multiva scanner with standard spine coil. Sagittal and axial T1-weighted, T2-weighted, STIR, MERGE, and coronal STIR sequences were analyzed for patient demographics, cause of injury, and associated vertebral, discal, ligamentous, and cord abnormalities. **Results:** Most patients were males (61.90%), predominantly in the 18–40 years age group (36.50%). Road traffic accidents were the major cause of injury. The lower dorsal and lumbar regions were most frequently involved. Bone marrow edema (20.63%) was the most common osseous finding. Intervertebral disc injury (33.33%) and cord edema (25.40%) were frequently observed, followed by cord compression (19.05%). **Conclusion:** MRI is an essential imaging modality for comprehensive evaluation of vertebral compression fractures. It provides detailed visualization of vertebral, ligamentous, and neural structures, facilitates early diagnosis, and aids in treatment planning and prognosis.

KEYWORDS : MRI, Vertebral Compression Fracture, Bone Marrow Edema, Spinal Cord Injury, Trauma

INTRODUCTION

Vertebral compression fractures can result from a range of underlying causes, including trauma, osteoporosis, or neoplastic involvement. Among these, osteoporotic compression fractures are particularly common, affecting nearly one-fourth of postmenopausal women and occurring less frequently in men of comparable age. In individuals younger than 50 years, trauma remains the predominant cause. Malignant vertebral compression fractures are often associated with metastatic spread from primary cancers of the breast, prostate, thyroid, or lung. Additionally, primary bone neoplasms and hematologic malignancies such as lymphoma and multiple myeloma may also contribute to vertebral collapse.

Magnetic Resonance Imaging (MRI) is considered the modality of choice for evaluating vertebral compression fractures due to its ability to demonstrate distinct morphological characteristics, signal intensity variations, and contrast enhancement patterns. In cases of spinal trauma, where the exact mechanism of injury is often uncertain, radiologists typically adopt a pragmatic classification based on vertebral body morphology. This approach evaluates the degree of vertebral height loss and the location of fracture lines. Osteoporotic compression fractures are generally categorized into three main types according to the position and orientation of these fracture lines.

- **Wedge Fracture:** This type primarily affects the anterior margin of the vertebral body, though in rare cases, the posterior margin may also be involved.
- **Concave or Biconcave Fracture:** In this pattern, the central portion of the vertebral body collapses, leading to a concave or "fish-mouth" appearance.
- **Crush Fracture:** This represents a more severe form of collapse, involving the anterior, posterior, and central portions of the vertebral body.

Each fracture type can be further categorized based on the extent of vertebral body height reduction, using a semi-quantitative grading system:

- **Grade I:** Retention of more than 75% of the original vertebral body height.
- **Grade II:** Vertebral height reduced to between 50% and 75% of normal.
- **Grade III:** Vertebral height reduced to less than 50% of its normal value.

In addition to evaluating vertebral height loss, it is crucial to assess the degree of deformation involving the spinal canal and neural foramina. In many spinal fractures, narrowing of the spinal canal occurs due to displacement or retropulsion of vertebral body fragments.

Mechanism of Injury: According to Denis' three-column theory of spinal stability, vertebral fractures are categorized based on the nature of the injury and the biomechanical forces involved.

Flexion–Compression Mechanism (Wedge or Compression Fracture): Anterior wedge compression fractures typically result from the combined effects of flexion and compressive forces. In this mechanism, the anterior column undergoes compression, with possible extension of injury to the middle and posterior columns depending on severity.

Three Major Subtypes are Recognized:

1. **Stable fracture:** Involvement is limited to the anterior column, producing anterior wedging of the vertebral body with less than 50% reduction in its height.
2. **Potentially Unstable Fracture:** Both the anterior column and posterior ligamentous complex are affected, leading to anterior wedging of the vertebral body, widening of interspinous spaces, and more than 50% loss of vertebral body height.
3. **Unstable Fracture:** All three spinal columns are compromised. Imaging typically reveals marked anterior wedging, disruption of the posterior vertebral body, and possible retropulsion of bone fragments into the spinal canal, which may compress the spinal cord or nerve roots.

Axial-Compression Mechanism (Burst Fracture): Burst or crush fractures occur due to intense axial compression forces acting on the vertebral column. Such injuries are commonly associated with high-energy trauma, including falls from a height, vehicular accidents, or sports-related impacts. These fractures are most frequently seen at the thoracolumbar junction, particularly between T5 and T8 vertebral levels.

Burst fractures are characterized by loss of vertebral body height, typically involving both the anterior and middle columns. The stability of the fracture depends on the integrity of the posterior column. When posterior elements are displaced or there is evidence of dislocation or

subluxation of the vertebral body or facets, the fracture is considered unstable. In severe cases, retropulsion of bone fragments into the spinal canal may occur, potentially compressing the spinal cord or nerve roots and occasionally leading to vascular injury.

Flexion–Distraction Mechanism (Chance Fracture): Chance fractures, also referred to as seatbelt injuries, result from a combination of flexion and distraction forces acting across the thoracolumbar spine. This injury typically involves the posterior column and may extend to the ligamentous structures. Such fractures are frequently associated with intra-abdominal injuries due to the mechanism of deceleration and flexion.

The pathophysiology of a Chance fracture is determined by the axis of flexion. The most common variant is the horizontal fracture type, in which the flexion axis lies anterior to the anterior longitudinal ligament (ALL), producing a horizontal split through the bony elements and disruption of the supraspinous ligament. Imaging usually demonstrates increased interspinous distance along with horizontal fracture lines involving the pedicles, transverse processes, or pars interarticularis.

In more severe flexion–distraction injuries, the axis of flexion lies posterior to the ALL, resulting in a combination of Chance and burst-type fractures. These are highly unstable injuries, often accompanied by buckling or retropulsion of the posterior vertebral cortex. The extent of neurological impairment depends on the degree of compression or damage to the neural elements.

MATERIALS AND METHODS

The present study was conducted in the Department of Radiology, involving a total of 63 patients who were referred for MRI evaluation. All MRI examinations were performed using a PHILIPS MULTIVA 1.5 Tesla MRI system equipped with a standard spine coil.

Inclusion criteria consisted of patients aged 18 years and above who presented with clinical symptoms and a history suggestive of spinal trauma. Patients were excluded if they had metallic implants, pacemakers, aneurysm clips, or recently implanted prosthetic valves, as well as those with metallic foreign bodies. Individuals who were clinically unstable or dependent on ventilator support, and those suffering from claustrophobia, were also excluded from the study.

Each patient underwent MRI evaluation in axial, sagittal, and coronal planes. A targeted examination of the clinically suspected region was carried out, along with a screening of the entire spine to assess the extent of injury and involvement of adjacent vertebral levels.

MRI Protocol:

All patients were evaluated using a standardized MRI spine protocol to ensure optimal visualization of vertebral anatomy and pathology. The recommended imaging sequences included sagittal T1-weighted, sagittal T2-weighted, and sagittal STIR sequences for overall assessment of vertebral alignment, marrow signal, and soft tissue changes. In addition, axial T1-weighted and axial T2-weighted sequences were obtained to evaluate the spinal canal, neural foramina, and posterior elements in detail. Sagittal MERGE sequence was included to enhance delineation of subtle fractures and ligamentous injuries, while coronal STIR sequence was performed to assess paraspinal soft tissue and ligamentous involvement.

RESULTS

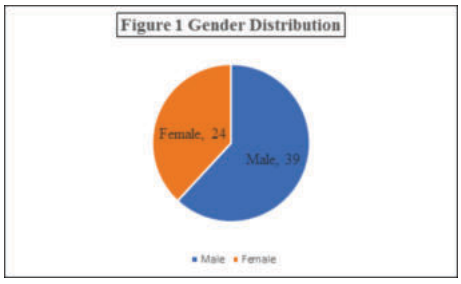
Assessment of Spine Injuries: Evaluation of spinal trauma cases was carried out based on several parameters, including age and sex distribution, mechanism of injury, and the presence of disc, ligamentous, cord, listhesis, osseous, and soft tissue injuries.

A total of 63 patients were included in the present study and classified into three age groups: 18–40 years, 41–60 years, and 61–80 years. The youngest patient in the study was 18 years old, while the oldest was 80 years. The highest number of cases were observed in the 18–40 years age group, comprising 23 patients (36.50%), followed by the 41–60 years group with 21 patients (33.33%), and the 61–80 years group with 19 patients (30.17%). (Table 1)

Table 1: Distribution of Patients According to Age

Age Group (Years)	Number of Patients	Percentage (%)
18 – 40	23	36.5
41 – 60	21	33.33
61 – 80	19	30.17
Total	63	100

Out of the 63 patients evaluated for vertebral compression fractures, 39 patients (61.90%) were males, while 24 patients (38.10%) were females. The results suggest that males were more frequently affected, indicating a higher susceptibility to acute compression fractures compared to females. (Figure 1)

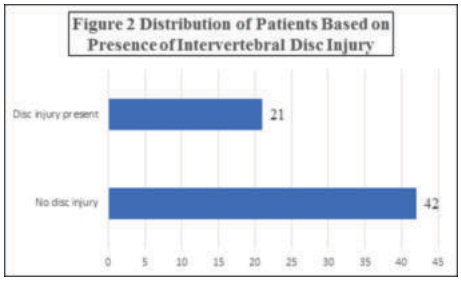


Among the 63 patients evaluated for traumatic vertebral compression fractures, the most frequent cause of injury was road traffic accidents, followed by falls from height and slip-and-fall incidents. This indicates that high-velocity trauma remains the predominant mechanism leading to compression fractures in the present study population. (Table 2)

Table 2: Distribution of Patients According to Cause of Injury

Cause of Injury	Number of Patients	Percentage (%)
Road Traffic Accidents	32	50.79
Fall from Height	21	33.33
Slip and Fall Injuries	10	15.88
Total	63	100

In the present study, out of 63 patients evaluated for vertebral compression fractures, 42 patients (66.67%) showed no evidence of intervertebral disc injury, while 21 patients (33.33%) demonstrated disc involvement, the most common finding being post-traumatic disc herniation. (Figure 2)



In the present study, intervertebral disc injuries were most frequently observed in the lumbar region, followed by the cervical and lumbosacral regions. No disc injuries were identified in the dorsal spine. (Table 3)

Table 3: Distribution of Intervertebral Disc Injuries According to Spinal Region

Region of Spine Involved	Number of Patients (n=63)	Percentage (%)
Cervical	7	33.33
Dorsal	0	0
Lumbar	10	47.62
Lumbosacral	4	19.05
Total	21	100

In the present study, most patients (96.83%) did not exhibit any ligamentous injury. Ligament involvement was observed in 2 patients (3.17%)—one with an isolated anterior longitudinal ligament (ALL) disruption and another with combined posterior longitudinal ligament (PLL) and ligamentum flavum injury. (Table 4)

Table 4: Distribution of Ligamentous Injuries in Patients with Vertebral Compression Fractures

Type of Ligamentous Injury	Number of Patients (n=63)	Percentage (%)
Absent	61	96.83
Isolated Anterior Longitudinal Ligament (ALL)	1	1.59

Isolated Posterior Longitudinal Ligament (PLL)	0	0
Both ALL & PLL	0	0
PLL and Ligamentum Flavum	1	1.59
Interspinous and Supraspinous Ligaments	0	0
Total	63	100

In the present study, cord edema or contusion was the most frequently observed spinal cord injury, followed by cord compression. Epidural hematoma was identified in only one patient, while no cases of cord hemorrhage were reported. (Table 5)

Table 5 Distribution of Patients According to Cord Injuries

Type of Cord Injury	No. of Patients (n=63)	Percentage (%)	Region of Spinal Cord Involved	Cervical	Dorsal	Conus Medullaris
Cord Compression	13	20.63	—	5	4	4
Cord Edema / Contusion	15	23.81	—	8	5	2
Cord Hemorrhage	0	0	—	0	0	0
Epidural Hematoma	1	1.59	—	0	1	0
Total	63	100	—	—	—	—

In the current study, 55 patients (87.30%) showed no evidence of listhesis injury. Anterolisthesis was identified in 4 patients (6.35%), while retrolisthesis was observed in 2 patients (3.17%). Additionally, 2 patients (3.18%) demonstrated traumatic subluxation or dislocation. (Table 6)

Table 6: Distribution of Patients According to Listhesis Injuries

Type of Listhesis Injury	No. of Patients (n=63)	Percentage (%)
Normal	55	87.3
Anterolisthesis	4	6.35
Retrolisthesis	2	3.17
Subluxation / Dislocation	2	3.18
Total	63	100

In the present study, lower dorsal (D9–D12) vertebrae were most commonly involved, followed by the lumbar region. The cervical spine was the least affected area, indicating that thoracolumbar junctions remain the most susceptible sites for compression fractures due to their biomechanical stress concentration. (Table 7)

Table 7: Distribution of Patients According to Region of Spine Involved in Compression Fractures

Region of Spine Involved	No. of Patients (n=63)	Percentage (%)
Cervical	3	4.76
Upper Dorsal (D1–D4)	4	6.35
Mid-Dorsal (D5–D8)	10	15.87
Lower Dorsal (D9–D12)	23	36.51
Dorso-Lumbar Junction	2	3.17
Lumbar	21	33.34
Total	63	100

In the present study, marrow edema was the most frequently observed osseous abnormality, followed by burst fractures and posterior element fractures. These findings highlight that marrow edema is a common indicator of acute vertebral injury detected on MRI. (Table 8)

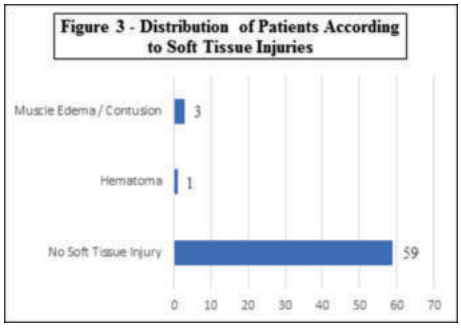
Table 8: Distribution of Patients According to Osseous Injuries

Type of Osseous Injury	No. of Patients (n=63)	Percentage (%)
Burst Fractures	5	7.94
Marrow Edema	13	20.63
Posterior Element Fractures	4	6.35
Total	63	100

In the current study, the majority of patients showed no evidence of soft tissue injury. However, muscle edema or contusion was observed in a few cases, while hematoma formation was identified in one patient, indicating that soft tissue involvement is relatively uncommon in vertebral compression fractures.

Table 9: Distribution of Patients According to Soft Tissue Injuries

Type of Soft Tissue Injury	No. of Patients (n=63)	Percentage (%)
No Soft Tissue Injury	59	93.65
Hematoma	1	1.59
Muscle Edema/Contusion	3	4.76
Total	63	100



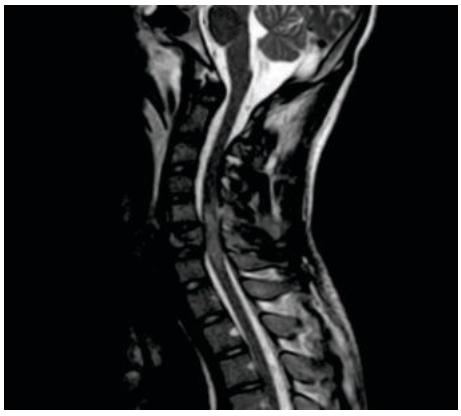


Figure 4 - Sagittal T2W Image Showing Hyperintense Signal Intensity From Lower Border of C5 to Upper Border of C7 Vertebral Level Suggestive Of Cord Edema.

Figure 5: Sagittal T2W Image Showing Anterolisthesis of L5 Over S1 and Anterior Wedge Compression Fracture of L4 Vertebral Body.

DISCUSSION

In the present study, 63 patients with spinal trauma were evaluated using Magnetic Resonance Imaging (MRI) to assess vertebral compression fractures and associated injuries.

The maximum number of patients belonged to the 18–40 years age group, accounting for 23 patients (36.50%), followed by 21 patients (33.33%) in the 41–60 years group, and 19 patients (30.17%) in the 61–80 years group. These findings indicate that compression fractures are most frequent in younger and middle-aged adults, which may be related to their higher exposure to road traffic and occupational hazards. Similar results were reported by Nalina et al., who observed that the most commonly affected age group ranged between 18–50 years. Likewise, Donald et al, Timothy et al., and Flanders et al. noted that individuals aged 16–30 years were most commonly affected, findings that are consistent with the present study.

In this study, males (61.90%) were more frequently affected than females (38.10%), suggesting that men are more prone to spinal

trauma due to greater involvement in outdoor activities, vehicular driving, and high-risk occupations. Elderly females who presented with compression fractures were predominantly those with slip or fall-related injuries. The gender distribution observed in this study aligns with the findings of Kerslake et al and is comparable to those of Roop Singh et al.

The most common cause of injury in our study was road traffic accidents, followed by falls from height and slip-and-fall incidents. This observation is in agreement with previous studies by various authors which also identified high-velocity trauma, particularly vehicular accidents, as the leading cause of spinal injuries.

Regarding intervertebral disc involvement, 21 patients (33.33%) demonstrated disc injuries, most frequently presenting as post-traumatic disc herniation. These findings are consistent with those of Katzberg et al., who also reported disc herniation as a common post-traumatic manifestation.

Among the spinal cord injuries, cord edema (25.40%) was the most frequently observed lesion, followed by cord compression (20.63%). Only one patient presented with an epidural hematoma. These findings correspond well with the studies conducted by Khandelwal et al., Kulkarni et al., and McArdle et al., who also identified cord edema as the predominant cord injury pattern in traumatic cases. MRI played a crucial role in identifying these cord abnormalities, helping to localize the lesion, assess its severity, and determine the cause of cord compression.

In terms of ligamentous injury, the majority of patients showed no evidence of disruption. Only two cases (3.17%) demonstrated ligament involvement — one with disruption of the anterior longitudinal ligament (ALL) and one with combined posterior longitudinal ligament (PLL) and ligamentum flavum injury.

Bone marrow edema was detected in 13 patients (20.63%), often associated with vertebral body compression fractures. This finding was statistically significant and supports the observation made by Mark A. Brinckman et al., who reported that marrow edema is more prominent in compression-type fractures than in distraction or non-compressive injuries.

Listhesis injuries were relatively uncommon, with 4 patients (6.35%) showing evidence of vertebral slippage — 3 cases of anterolisthesis and 1 case of retrolisthesis.

With regard to soft tissue involvement, most patients did not show significant findings. However, one patient (1.59%) presented with a hematoma, and three patients (4.76%) exhibited muscle edema or contusion.

Overall, MRI proved to be an indispensable imaging modality in evaluating spinal compression fractures, allowing comprehensive assessment of osseous, ligamentous, discal, cord, and soft tissue injuries, thereby aiding in accurate diagnosis and guiding appropriate management.

CONCLUSION

From the present study, it can be concluded that vertebral compression fractures are more frequently observed in males than in females and are most prevalent in the 18–40 years age group. The predominant mechanism of injury was road traffic accidents, followed by falls from height, while slip-and-fall injuries were more commonly reported among females.

Among osseous injuries, bone marrow edema emerged as the most common finding, underscoring the significance of MRI as the only imaging modality capable of detecting marrow changes at an early stage. The most frequent spinal cord injury pattern identified was cord edema, followed by cord compression.

MRI proved invaluable in not only identifying spinal cord abnormalities but also determining the extent, location, and severity of lesions, as well as the underlying cause of cord compression. In patients with polytrauma, MRI facilitated the detection of multilevel and clinically unsuspected injuries, allowing for timely management and improved prognostication.

Overall, this study emphasizes that Magnetic Resonance Imaging plays a pivotal role in the comprehensive evaluation of spinal compression fractures, especially for assessing osseous, ligamentous, discal, cord, and soft tissue injuries. It should be considered the primary diagnostic and prognostic imaging tool in patients with suspected or confirmed vertebral compression fractures to ensure accurate diagnosis, guide prompt treatment, and aid in predicting neurological recovery.