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Research Paper

Magnetic Resonance Imaging (MRI) Based Scoring System to Differentiate Solitary Osteoporotic from Malignant Vertebral Compression Fractures

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ABSTRACT:

BACKGROUND:

Discriminating a pathological from osteoporotic vertebral compression fractures is sometimes challenging.

OBJECTIVE:

To create scoring system using several MRI signs, trying to correctly differentiate osteoporotic from malignant compression vertebral fractures.

PATIENTS AND METHODS:

A cross sectional study was performed in MRI unit of Al-Imamain Al-Kadhemain Medical City/ Baghdad/Iraq, 68 patients (24 males and 44 females) were included, all patients were presenting with acute back pain and x-ray evidence of compression fracture of vertebral body. MRI was done within 2 months from onset of symptoms and follow up for at least 4-6 weeks. A total of 9 MRI signs were evaluated in terms of sensitivity, specificity and accuracy in diagnosis of malignant fractures. A stepwise analysis of these signs was used to create a scoring system to differentiate malignant from osteoporotic vertebral compression fractures.

RESULTS:

Malignant vertebral fracture was diagnosed in 13 patients and osteoporotic vertebral fracture was found in 55 patients. All used MRI signs had a variable specificity and sensitivity for diagnosis of malignant fractures but all are statistically significant except one. Mean score for patients with malignant vertebral fractures was 3.5 (range of 3-6), while Mean score in patients with osteoporotic vertebral fractures was 2.1 (range of 0-4). The optimum score cutoff value was 4 with 61.5% sensitivity, 81.8% specificity, 79.4% accuracy and statistically significant (P-value=0.012) for the discrimination of malignant from osteoporotic vertebral compression fractures.

CONCLUSION:

Convex posterior vertebral border, asymmetrical diffuse or rounded abnormal bone marrow signal, involvement of the pedicle, and paravertebral soft tissue mass are highly suggestive MRI sign of malignant fracture. Post contrast enhancement is not a specific sign. Fluid cleft sign is suggestive of osteoporotic fracture. This simple scoring system could be useful tool for the differentiation of malignant and osteoporotic vertebral fractures with the best accurate cutoff value is 4.

KEYWORDS: Magnetic resonance imaging, malignant vertebral compression fracture, Osteoporotic vertebral compression fracture.

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INTRODUCTION:

Vertebral fractures caused by benign or malignant lesions are common among the elderly [(1)]. Metastatic disease to the spine is the most frequent spinal tumour [(2)]. Identifying the cause of fractures is critical to determine the clinical course, treatment, and prognosis [(3,4)]. The final diagnosis of a metastatic disease is based on biopsy; however, not all patients can undergo biopsy because the procedure is invasive [(5)].

Magnetic resonance imaging (MRI) provides a noninvasive morphologic evaluation of the lumbar spine and shows the relationship between structural findings and disc herniation [(6)]. Magnetic resonance imaging (MRI) is an excellent method to

differentiate between OVF and MVF [7], it can provide the basis for the distinction as each has its own characteristic findings [1, 4, 8-10]. A high index of suspicion depending on the initial MR images [11] where multiple-image findings are used to discriminate MVFs from OVFs [1,4,12,13], however, none of these imaging findings have definite sensitivity and specificity, and no single finding is conclusive for the diagnosis [1,11,14,15]. Integrating characteristic image findings can improve the differential diagnosis and overall accuracy. Discriminant analysis is an accepted statistical method which combines multiple features to characterize 2 or more classes of clinical issues [16-18]. A prediction model that combines multiple image findings making and a scoring system for differentiating between MVFs and OVF is one solution to and can be used in surgical decision making [19].

AIM OF THE STUDY:

Trying to use a scoring system using several MRI signs and trying to correctly differentiate osteoporotic from malignant compression vertebral fractures.

PATIENTS AND METHODS:

From December 2021 to December 2022, cross sectional study was conducted on 68 patients (24 male and 44 female). The study was done in the radiology department of AL-Imamain AL-Kadhemain Medical City/ Baghdad/ Iraq. The patients were presenting with acute back pain and vertebral body compression fracture on x-ray. MRI was done within 2 months from onset of symptoms.

Ethical approval: this study was approved by the scientific committee of Iraqi Board of Diagnostic Radiology. Verbal informed consent was obtained from all patients included in the study.

Inclusion criteria: patients presented with solitary vertebral body compression fracture evident on X-ray during 60 days from the clinical onset.

Exclusion criteria: previous history of severe trauma (road traffic accident or high falling injury), chronic vertebral fractures (no abnormal bone marrow SI, or >60 days from onset of back pain), patients who had already received spinal irradiation (because this may result in bone marrow changes), patients for whom adequate follow up could not be obtained, patients with multiple vertebral fractures, and general contraindications to MRI examination.

Magnetic resonance imaging (MRI) acquisition: all MRI imaging were done by a 1.5-T machine (Magnitom Avanto, Seimen's medical system, Germany) using a phased-array spine coil using the following pulse sequences: Sagittal T1 WI (TR/ TE 622/9.9msec), slice thickness 4mm, FOV 280 mm and intersection gap of 1mm, Sagittal T2 WI (TR/TE 4120/99 msec), the slice thickness 4 mm, FOV 280 mm, and intersection gap 1mm, Sagittal Short Tau Inversion-Recovery (STIR) fast spin-echo image (TR/TE 4510/99 msec), slice thickness 4mm, FOV 280 mm and intersection gap 1mm, Axial T2 (TR/TE 4604/99 msec), slice thickness 4 mm, FOV 244 mm, and intersection gap 1mm and T1 WI sagittal ± FS and axial images were repeated after gado-pentetate dimeglumine intravenously in a dose of 0.1 mmol/kg.

MRI imaging analysis: a 9 key MRI signs previously proposed in the literatures were applied to image evaluation. These signs are:

1. Pattern of abnormal BM signal intensity of fractured vertebra (band like, rounded or diffuse). 2. The shape of anterior or posterior wall border by sagittal image (sharp or convex). 3. Abnormal signal intensity involving the pedicle or posterior element, 4. Presence or absence of fluid cleft sign. 5. Asymmetry of signal intensity change on axial image. 6. Pattern of posterior wall protrusion on axial image (single vs double peaked wall). 7. Presence of encasing epidural mass (encircling the entire thecal sac) or the presence of paraspinal soft tissue mass. 8. Compression of cord by protruded fractured vertebra, and 9. Contrast enhancement of fractures.

The abnormal bone marrow signal of the vertebral bodies was considered hypointense, isointense, or hyperintense in comparison with the signal intensity of normal vertebrae on T1- and T2-weighted images in the same patient.

All patients were followed by a second MRI for at least 4-6 weeks from first MRI study, the malignant nature of the fractures was considered when there was history of primary tumour, progressive deterioration or newly developed spinal lesions at follow-up MR imaging and bone scintigraphy. When the radiological findings on follow-up did not progress in patient without a clinical history of malignancy and the patient was clinically improved, the fracture was considered to be a benign OVF.

Clinical parameters of follow up were pain, laboratory investigations such as serum alkaline phosphatase level, and the disease status of the primary neoplasm according to the treatment and PET scan results. Accordingly, the 68 patients included in this study with solitary vertebral body

fracture, 55 of them having acute benign vertebral osteoporotic compression fracture (OVF) and 13 with malignant vertebral body fracture (MVF).

The usefulness of the above mentioned MRI signs was investigated in terms of sensitivity, specificity and accuracy, trying to evaluate their ability to support diagnosis of MVFs. Those MRI signs were set as variables, and each variable accorded a certain integer number either 1 or 0 depending on their efficiency in MVF diagnosis to create simple scoring system, as described by table below:

1. Pattern of abnormal vertebral signal (round 1, diffuse 1, band like 0), 2. Posterior border (convex 1, sharp 0), 3. Fluid cleft signs (presence 1, absent 0), 4. Asymmetry of abnormal SI (presence 1, absent 0), 5. Pedicle involvement (presence 1, absent 0), 6. Posterior wall protrusion (double peaked 1, single peak 0), 7. Contrast enhancement (positive 0), 8. Spinal cord compression (positive 1, negative 0), and 9. Para-spinal soft tissue mass (positive 1, negative 0)

Subsequently, the total mean score for benign and malignant groups was calculated and the optimum cutoff value from these scores has been estimated in order to discriminate MVFs from OVFs.

Statistical analysis: was done using the statistical package of SPSS-28 (Statistical Packages for Social Sciences- version 28). Data were categorized in simple measures of frequency, percentage, mean, standard deviation, and range (minimum-maximum values).The significance of difference of different percentages were tested using Pearson Chi-square test (χ2-test) with the application of Yate's correction or Fisher Exact test whenever applicable. The level of statistical significance was considered when the P value was equal or less than 0.05. Receiver Operating Characteristic "ROC" curve analysis was used in order to evaluate the diagnostic performance of previously mentioned MRI sings in differentiation of MVFs and OVFs and to demonstrate the ideal "cut-off value" for the calculated score to differentiate between malignant and benign vertebral fractures.

RESULTS:

Sixty-eight patients with solitary vertebral body fracture were included, 55 of them having OVF and 13 with MVF. The mean age in OVF group (64.0±11.0) and the MVF group (60.3±11.9. Females were higher than males (44 females and 24 males), however, male gender show higher percent in MVF group (53.8%) while females were more in OVF group (69.1%).

Dorsal and lumber vertebral bodies levels are equally affected in MVF group (46.2% each) with one sacral vertebra involved (7.7%). On other hand, lumber level was affected in higher proportion of benign OVFs (69.1%) but this was not statistically significant (P value =0.055).

MRI signs: rounded pattern of abnormal BM signal was found in 3 MVFs (23.1% sensitivity, 100% specificity and 85.3% accuracy for MVF diagnosis), while the remaining 10 MVFs show diffuse abnormal signal (76.9% sensitivity and 52.7% specificity), the later sign is also seen at 26 OVFs (47.3%), band like pattern present in remaining 29 OVFs (52.7%), these findings were statistically significant (P value 0.0001) as shown in Table (1).

Convex posterior wall of vertebra shows a highly significant results for the diagnosing MVF (P value= 0.0001) seen in 10 malignant fracture with 76.9% sensitivity, 94.5% specificity and 91.2% accuracy as shown in Table (1).

Cleft signs were not statistically significant (p value=0.389) in diagnosing MVFs, (seen only in 3 OVFs and negative in all MVFs), with sensitivity of 100% if negative and low specificity 5.5%.

Asymmetrical BM signal intensity and double peaked posterior border were found to be present in all MVF group with 100% for the sensitivity, specificity and accuracy and significant predictive value (P value = 0.0001) as shown in Table (1).

Abnormal signal intensity of the pedicles was detected in all MVFs and 2 of the OVFs (3.6%), with 100% sensitivity, 96.4% specificity and 97 % accuracy for MVF diagnosis.

Statistically significant results were also noted with spinal cord compression (P value= 0.007) and paravertebral soft tissue mass lesion (P value= 0.003) with high specificity of both in diagnosing MVF (90.9%, 100% respectively), but low sensitivity (38.5% and 15.4 % respectively) as shown in Table (1).

Contrast enhancement of fractured vertebral bodies was noted in all MVFs (100% sensitivity, 27.3% specificity) and in 40 OVFs (72.7%) with 41.2% accuracy in diagnosing MFV as presented in Table (1).

Table 1: **Distribution of the key MRI findings between MVF and OVF groups.**

	MRI Signs		MVF		OVF		P value	Sensitivity	Specificity	Accuracy
			No.	%	No.	%				
1	Pattern of abnormal signal	Round	3	23.1			0.0001*	23.1	100	85.3
		Diffuse	10	76.9	26	47.3		76.9	52.7	57.3
		Band			29	52.7				
2	Contour of posterior wall	Convex	10	76.9	3	5.5	0.0001*	76.9	94.5	91.2
		Sharp	3	23.1	52	94.5				
3	Cleft sign	Negative	13	100	52	94.5	0.389	100	5.5	23.5
		Positive	-	-	3	5.5				
4	Symmetry	Asymmetrical	13	100	-	-	0.0001*	100	100	100
		Symmetrical	-	-	55	100				
5	Pedicle	Positive	13	100	2	3.6	0.0001*	100	96.4	97
		Negative			53	96.4				
6	Posterior wall (axial)	Double	13	100	-	-	0.0001*	100	100	100
		Single	-	-	55	100				
7	Contrast	Positive	13	100	40	72.7	0.033*	100	27.3	41.2
		Negative	-	-	15	27.3				
8	Spinal cord compression	Positive	5	38.5	5	9.1	0.007*	38.5	90.9	80.9
		Negative	8	61.5	50	90.9				
9	Paravertebral soft tissue	Positive	2	15.4	-	-	0.003*	15.4	100	83.8
		Negative	11	84.6	55	100				

*Significant difference between percentages using Pearson Chi-square test (χ^2-test) at 0.05 level.

MRI score: the mean MRI score in patients with MVFs was 3.5 with a range of (3-6), while the Mean MRI score in patients with OVFs was 2.1with a range of (0-4).

Pairwise comparison was then performed and expressed by the Receiver operating characteristics curve (ROC) curve, this shows significant difference between OVFs and MVFs, with an optimal cutoff value of mean scores of all 9 radiographic signs to detect patients with high likelihood for developing malignant fracture was 0.4000 (i.e. score 4) with optimum sensitivity of 61.5%, specificity of 81.8%, positive predictive value (PPV) 40%, negative predictive value (NPV) 82.5%, and fair area under the ROC curve (AUC) is 0.724 ± 0.082,(P= 0.012) which means it is statistically significant. Figure 1 and 2 show MRI images of 2 patients included in the study.

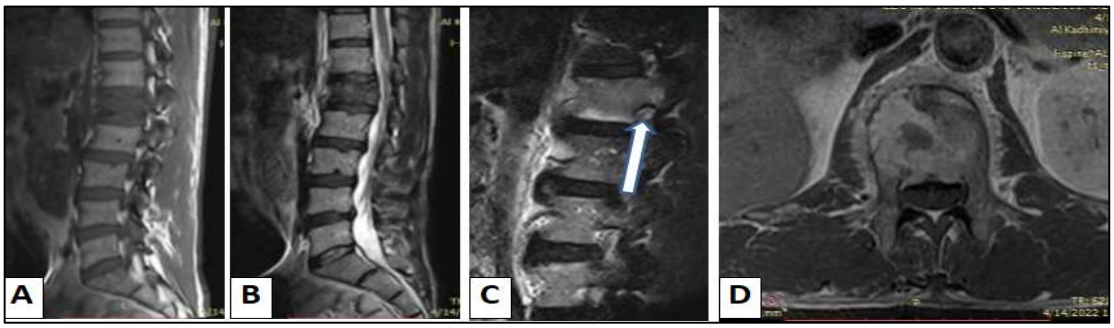

Figure 1: 61 years old male with negative PMH; A:T1 SE sagittal image shows compression of L1 vertebral body with diffuse abnormal bone marrow signal intensity (SI), B:T2 SE sagittal image shows convex posterior wall border, C: axial T1 post contrast image shows double peaked posterior border with asymmetrical SI and post contrast enhancement, D:T2 fs sagittal image demonstrate pedicle involvement (white arrow). A total score is 5. MVF was diagnosed after follow up.

Figure 2: 56 years old male with negative PMH. A: T1 SE sagittal image shows compressed L2 vertebral body with diffuse abnormal SI, B: Sagittal T1 post contract image shows enhancement, C: T2 fs sagittal image shows convex posterior border, D: axial T2 SE image shows single peaked posterior wall with symmetrical SI and spinal cord compression. A total score was 3. Benign osteoporotic acute compression fracture OVF, was diagnosed.

DISCUSSION:

The differentiating between OVFs and MVFs is a common problem and reaching the final diagnosis is important for selecting the type of treatment and predicts the prognosis [20]. In the literatures only 3 previously reported studies were attempted to use a scoring systems to discriminate MVF from OVF [7,11, 21].

Regarding to pattern of abnormal signal intensity of malignant fractures, the current study showed high specificity of round pattern (100%) but low sensitivity (23.1%), these results were similar to that reported in the previous studies [11,21]. On the other hand, diffuse pattern of abnormal signal found to be highly sensitive for MVFs (76.9%) but lower specificity (52.7%) than round appearance, this result was different from that reported in the previous studies [11,21] where they found high sensitivity and specificity of this sign for MVF diagnosis (62% sensitivity with 91% specificity) in Kato S et al [11] study and (79% sensitivity with 91% specificity) in Li Z et al [21] study. This difference can be explained by the fact that they include larger malignant cases in their studies. Conversely, band like abnormal signal is found only in 52.7% of OVFs and never seen in MVFs, this finding was consistent with that reported in the previous studies [21-23].

In the current study, vertebral body convex posterior border was found more frequent in MVF than OVF (76.9% vs 5.5%) with high specificity and sensitivity; these results were in agreement with the previously reported studies [7,11,21].

This study found that fluid cleft sign was seen in only 3 cases of benign fractures and never in MVF suggesting it is highly specific sign for benign OVFs but with low sensitivity, this result was similar with that reported in previous studies [11,21,23,24].

The current study showed that asymmetrical bone marrow signal abnormality is statistically significant for diagnosis of MVF, with high sensitivity and specificity, this result was consistent with previously reported studies [4,7,11,21,25].

Double peaked posterior vertebral border is found to be highly sensitive and specific for diagnosis of MVFs in this study. Kato S et al [11] and Li Z et al [21] studies showed high specificity but low sensitivity of this sign, this difference can be explained by the difference in sample volume as they include larger numbers of malignant fractures.

Involvement of the pedicle by abnormal signal intensity was noted to be sensitive and specific for MVFs diagnosis, this finding was consistent with some previously reported studies [4,7,11,21], on the other hand, Ishiyamaa et al [26] stated that the involvement of the pedicle was seen frequently in patients with OVFs and was not specific for malignant disease and this may be attributed to the inclusion of a large number of osteoporotic fractures (n=225) compared to only (19) malignant fractures in their study.

In the current study the sensitivity of post contrast enhancement for malignant fracture was high but with low specificity and low accuracy to differentiate both conditions, these results were similar to those in the previous studies [4, 27]. However, another studies by Geith et al [28], and

Arvealo et al [29] showed significant difference of enhancement between MVFs and OVFs. This discrepancy can be attributed to the use of a quantitative analysis of dynamic contrast enhancement (DCE) MRI perfusion parameters and including acute as well as chronic vertebral fractures within their samples.

In this study spinal cord compression was found to have low sensitivity (38.5%) but high specificity (90.9%) for MVF. These results was different from Yuzawa et al [7] study which detects it in 93% of MVF and 29.8% of OVF (93% sensitivity and 35% specificity). This difference may be attributed to the difference in inclusion and exclusion criteria between the 2 studies.

The current study found that the paravertebral soft tissue mass adjacent to fractured vertebra was detected in only 2 of MVFs indicating very high specificity (100%) but low sensitivity (15.4%), these results were consistent with those observed in earlier studies where they found that it is highly accurate sign for differentiation with high specificity but low sensitivity [7,11,21].

The best cutoff value of the simple scoring system for discriminate between MVFs and OVFS with optimum sensitivity and specificity, was 4 (total score ≥4 indicates MVF whereas total score < 4 indicate OVF). Li Z et al [21] study in China demonstrated a cutoff value of 4 with accuracy rate 98.3%. Another study by Kato S et al [11] in Japan showed a cutoff value of 5 with 96.6 % accuracy. It seems possible that this discrepancy in accuracy rates was due to multiple factors like difference in sample size, different ethnicity groups, difference in the number of included radiological signs in analyses, the use of CT scan parameters in addition to MRI in their studies, in addition to image judging criteria and interobserver variability.

CONCLUSION:

Convex posterior vertebral border, asymmetrical diffuse or rounded abnormal bone marrow signal, involvement of the pedicle, and paravertebral soft tissue mass are highly suggestive MRI sign of malignant fracture. Post contrast enhancement is not a specific sign. Fluid cleft sign is suggestive of osteoporotic fracture. This simple scoring system could be a good method for the differentiation of malignant and osteoporotic vertebral fractures with the best accurate cutoff value is 4.

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