Original Research Article

Magnetic Resonance Diffusion Tensor Imaging in Differentiating Benign and Malignant Compressed Vertebrae

Abstract

Background: There are several causes of vertebral compression fractures (VCFs), includingneoplastic infiltration, osteoporosis, andtrauma.Our objective was to examine the diagnostic accuracy of magnetic resonance diffusion tensor imaging (MR-DTI) in differentiating benign from malignant compressed vertebrae. This prospective research was carried out on a selected group of 30 cases with compressed vertebral fracture diagnosed by other imaging modalities and a control group of 30 subjects referred to MR unit of Radiodiagnosis Department at the Local University Hospitals.Inclusion criteria were adult patients, both sexes, Patients with compressed vertebral fracture diagnosed by other imaging modalities.

Results: According to ROC analysis for detecting specificity and sensitivity of FA, ADC and mean diffusivity quantitative analysis of DTI MRI to differentiate between malignant and benign VCFs in cases group, we can see that the ROC for FA gives AUC 0.886 while ADC gives AUC 0.886 and MD gives AUC 0.922,with specificity and sensitivity of FA 85.71% and 93.75%respectively, while specificity andsensitivity of ADC 92.86% and87.50% respectively and specificity and sensitivity of MD 92.86%and 87.50% respectively.

Conclusions:DTI with its quantitative indicators is a valuable method in differentiating malignant from benign compressed vertebrae when compared to conventional MRI. FA values in benign vertebral fracture were significantly less than the FA values in malignant vertebral fracture.

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Keywords: Magnetic resonance diffusion tensor, benign, malignant compressed vertebrae

Introduction:

There are several causes of vertebral compression fractures (VCFs), includingneoplastic infiltration, osteoporosis, andtrauma. Osteoporotic VCFs occur less commonly in males of comparable age than they do in postmenopausal women, who have a prevalence of about 25%. Trauma is the most prevalent cause among cases younger than 50 years of age;while, multiple cancers, such as prostate, breast, lung, and thyroid, have bone metastasis tendencies, which can result in malignant VCFs [(1)].Bone metastasis occurs most commonly in thevertebral bone marrow (BM),with high morbidity. One-third of oncologic patients suffer from benign vertebral collapse owing to osteopenia, even though vertebral BM is the most prevalent location of bone metastases.So,determining if the cause of VCFis malignant or benignis important [(2, 3)].

It is crucial for physician to distinguish between malignant and benign osteoporotic VCFsto startproper treatment and improve outcome, which can be difficult in practice [(4)]. VCFs are often detected and characterized by magnetic resonance imaging (MRI) of the spine. Confident distinction,however, is not always achievable; as conventional MRI, malignant VCFshave similarmorphologic changes and signal intensities to acute osteoporotic VCFs, which necessitate invasive bone biopsy to confirm the nature of the VCF; however, sampling error may occur, or it could be inconclusive[(5-7)].

A new MRI technique,diffusion tensor imaging (DTI), provides information for assessing the biological tissues microstructure by producing 3D maps of the movements from water molecules. DTI relies on the water molecules’capacity to flow differently in various directions across the anisotropic biological tissue. Anisotropic diffusion happens preferentially in a single direction as opposed to being uniform in all directions. The tissue's cell walls inhibit the diffusion of substances in the opposite direction[(8, 9)].

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By measuring the apparent diffusion coefficient (ADC), it is possible to quantify the disturbances (increase or restriction) of diffusion. Diffusion is also measured in different ways in DTI; as mean diffusivity (MD), the overall diffusion amount in a voxel or sample, and fractional anisotropy (FA), the degree to which diffusion is confined to certain directions [10].The expression of FA as a scale thatranges from 0 (representing the unrestricted diffusion in all directions) to 1 (representing theunrestricted diffusion in single direction only), as in healthy tissues. The estimated MD provides the totalwater diffusion magnitude; changes in tissue density will influence these indicators by changing the direction of water motion. [11, 12].

Our objective was to examine the diagnostic accuracy of magnetic resonance diffusion tensor imaging (MR-DTI) in differentiating benign from malignant compressed vertebrae.

Patients and Methods:

This prospective research was carried out on a selected group of 30 cases with compressed vertebral fracture diagnosed by other imaging modalities and a control group of 30 subjects referred to MR unit of the Local University Hospitals over a period from March 2022 till March 2023.

Inclusion criteria were adult patients, both sexes, Patients with compressed vertebral fracture diagnosed by other imaging modalities.

Exclusion criteria were pediatric patients, Subjects refusal to precipitate in the study.

Subjects with MRI contraindication such as having any metallic implants as aneurysm clips, pacemaker or any other magnetically activated or electronic implants,and alsocases with claustrophobia, andpatients with vertebral body fixation with screws.

All patients and controls underwent the following:

Proper history taking form all the patients including personal history: name, sex, age, address, occupation and telephone number, present history: duration, onset, and course of the

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presenting symptoms as pain and immobility, past history ofprevious spinal disease, spinal trauma, previous spinal operation, neoplastic lesions, any systemic disease (as HTN or DM), and previous neurological diseases.

Clinical examination.

MRI examination: The study was performed using 1.5 T MRI General Electric machine (closed magnet). The subjects were in neutral supine position. Imaging was carried using a spine coil.Before entering the examination room, the studied subjects were told to remove any metallic and other ferromagnetic items. During the duration of the assessment, the cases were instructed to maintain complete stillness. The subjects didn't require any specific preparation before MRI.

The MRI pulse sequences that were included are: -

Routine MRI sequences: Sagittal T1 weighted fast-spin-echo sequence (T1WFSE): (TR/TE= 440/8.2 ms,field of view(FOV)= 34x34, Flip angle 160°, 5 mm thickness, NEX: 2 and Matrix: 320 * 192).

Axial T1WFSE: (TR/TE = 470/8.1, FOV= 24x21.6, Flip angle 160°, 6 mm thickness, NEX: 2 and Matrix: 256 * 192).Sagittal T2 weighted fast-spin-echo sequence (T2WFSE): (TR/TE= 2751/110.6, FOV=26x26, Flip angle 160°, 3,7 mm thickness, NEX: 2 and Matrix: 320 * 224). AxialT2WFSE: (TR/TE= 2415/106.9, FOV=24x24, Flip angle 160°, 6 mm thickness, NEX: 2 and Matrix: 320 * 192).

Diffusion tensor imaging MRI (DTI MRI):

A diffusion weighting factor of (b-value = 1000 s/mm^2).A single shot,using (20-25) diffusion encoding directions, of echo planar imaging (EPI) sequence was taken.The overalltime of scanning was 9 min.

Sagittal plane was used for acquiring the image, with slice thickness of 4 mm, image matrix of 96x 48 mm, with a FOV of 34 x 34 mm, and no inter-slice gap. Magnitude constructed

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images were repeated (averages = 4) and temporally averaged to reduce the phase fluctuations and enhance the signal-to noise ratio.TR/TE= 2075/63.9 msec, FOV=34x34, slice thickness 4 mm, NEX:10 and matrix 96x48 mm.

Image processing:

Evaluation of the MR images of both patients and control groups was carried out by two radiologists using offline separate workstation (advantage window 4.7).Conventional MRI image were analyzed for changes in the scanned compressed vertebrae and abnormal SI.DTI data were analyzed using offline separate workstation, the ROIs were taken at the center of the compressed vertebrae avoiding the articular plate.

Using theloaded program,**color coded map images** were obtained automatically;based on the color mapping images, they usually contained three or more colors commonly red, blue and green mainly and sometimes a mixture between them.Quantitative analysis was conducted to calculate FA, MD and ADC form the ADC and FA maps for every ROI.The data obtained from standard sequences, FA map, MD map, and ADC map,were compared in cases and control group.

Statistical analysis

statistical analysiswas performed using Statistical Package for Social Sciences (SPSS) program V20 (IBM SPSS Inc, ARMONK, NY, USA). Quantitative variables were presented as mean ± Standard deviation (SD) and range. Student's t-test was utilized to compare between two independent groups of parametric data (normally distributed variables). ANOVA (analysis of variance) test was utilizedto comparequantitative data among different times in the same group. Categorical variables were presented as numbers and percentages, and analyzed using Chi square test ($\chi 2$). For the calculation of the diagnostic accuracy of quantitative variable in predicting categorical outcome,Receiver operator characteristic (ROC) curve was tested.P-value <0.05 was deemed significant.

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Results:

This prospective research included two groups; a control group of 30 subjects; 15 of them were females (50%) and 15 were males (50%),with an age range from 34 to 70 years old, with a mean of 56.000 ± 11.256, and a patient group including 30 cases with vertebral fractures; 8of them were females (26.67%) and 22 were males (73.33%), with an age range from32 to 79 years old, with a mean of 56.333 ± 12.491. Most of the casesaged from 51 to 60 years; 13 cases, representing 43.33%. Sex and age distribution of the studied subjects in both groups **Table (1)**.Nine of the studied patients were asymptomatic while 21 patients presented with back pain and 6 patients presented with limitation of movement as shown in **Table (2)**

As Regards the final outcome of the studied casesbased on histopathological findings, clinical history of the patients as well as follow up studied which were accepted as a standard reference, the patient group was classified into two subgroups based on the nature of vertebral fractures: 14 cases with benign vertebral fractures (46.67%), and 16 caseswith malignant vertebral fractures (53.3%). According to the etiology of vertebral fractures, it was trauma in 8 patients (26.67%), osteoporosis in 6 patients (20%), multiple myloma in 8 patients (26.67%), metastases in 6 patients (20%), lymphoma in 1 patient (3.33%), and meningioma in 1 patient (3.33%) Among the studied patients, 5 patients had multiple vertebral fractures; 3 of them had multiple myeloma fractures, 1 had metastatic fractures and 1 had traumatic fractures as demonstrated in **(Table 3)**.

After analyzing all MRI studies in the cases group, there was 17 lumbar fractures (48.57%), 13 dorsal fractures (37.14%), 3 cervical fractures (8.57%) and 2 sacral fractures (5.71%) In control group, cervical, dorsal, and lumbar regions were examined; each region was examined at 10 subjects as shown in **(Table 4)**.

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Conventional MRI revealed loss of height of all the examined fractured vertebral bodies in 30 patients (100%). Abnormal SI of BM was noted in 14 patients (46.67 %), lesions in other vertebrae were found in 12 patients (40.00%), expanded post vertebral contour was found in 10 patients (33.33%), abnormal posterior element signal was found in 9 patients (30.00%), paravertebral soft tissue was found in 7 patients (23.33%), and spinal cord compression was found in 7 patients (23.33%) as shown in **(Table 5)**.

Regarding DTI MR imaging, quantitative assessment was performed in all the fractured vertebral bodies in the studied patients using FA, ADC and MD parameters and compared to those of the normal vertebra in the control group. In the cases group, the mean FA value in benign vertebral fracture (0.253±0.114) **(Figure 2)**was less than the mean FA value (0.419±0.094) **(Figure 3)** in malignant vertebral fracture compared to the mean FA in control group (0.807±0.066) **(Figure 1)**, with statistical significance (p value <0.001).Also, the mean ADC value in benign vertebral fracture (1.579 ±0.368) **(Figure 2)** was higher than the mean ADC value (0.884±0.253) **(Figure 3)**in malignant vertebral fracture compared to the mean ADC in control group(0.291±0.050) **(Figure 1)**, with statistical significance(p value <0.001).In the patient's group, the mean MD value in benign vertebral fracture (1.605±0.363) **(Figure 2)** was higher than the mean MD value (0.878±0.242) **(Figure 3)** in malignant vertebral fracture compared to the mean MD in control group (0.262±0.065) **(Figure 1)**, with statistical significance (p value <0.001) as illustrated at **(Table 5).**

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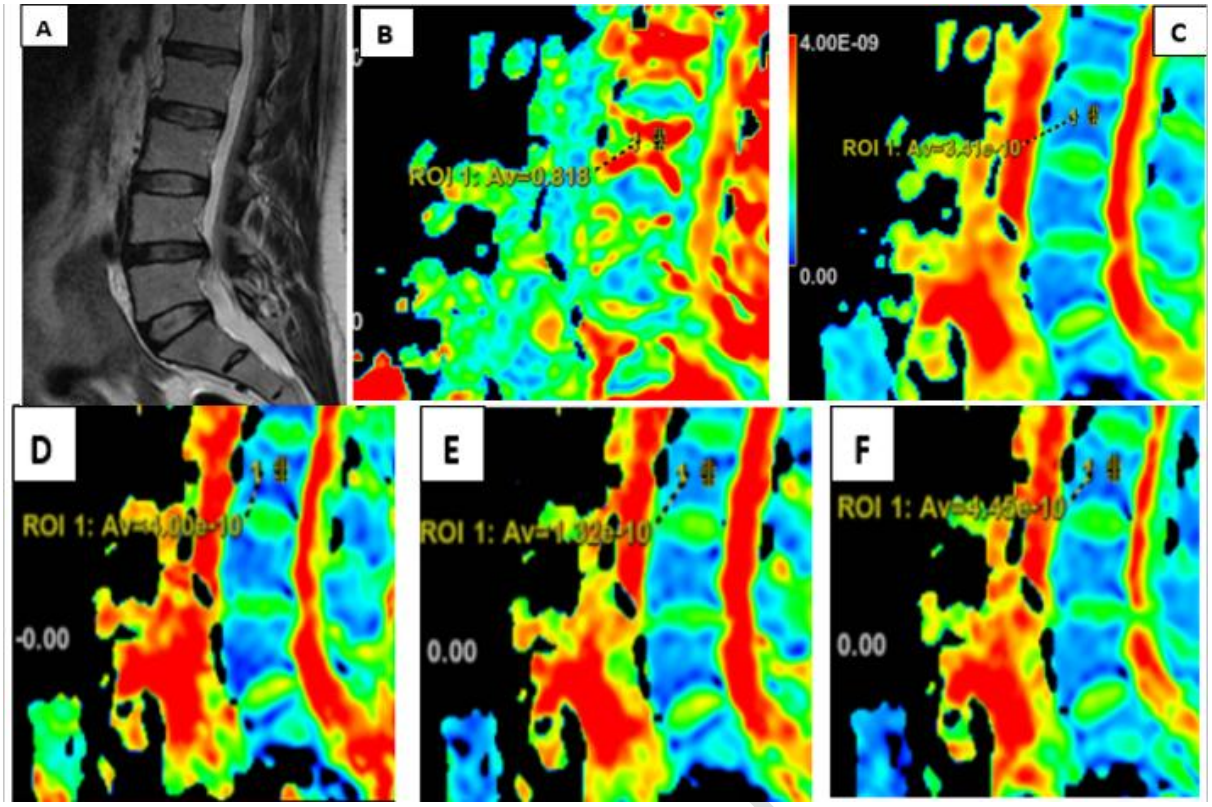

Figure (1): (A-F images): A 43-year-old healthy female subject at the control group (A) Sagittal T2-weighted MR image acquired at 1.5 T shows normal osseous alignment, no abnormal marrow signal or abnormal cord signal, (B) Sagittal color coded FA map image shows FA value at the vertebral body (0.818), (C) Sagittal color coded ADC map image shows ADC value at the vertebral body (0.341), and (D, E& F) Sagittal color coded diffusion coefficient images at (X,Y,Z) with increased MD (0.325).

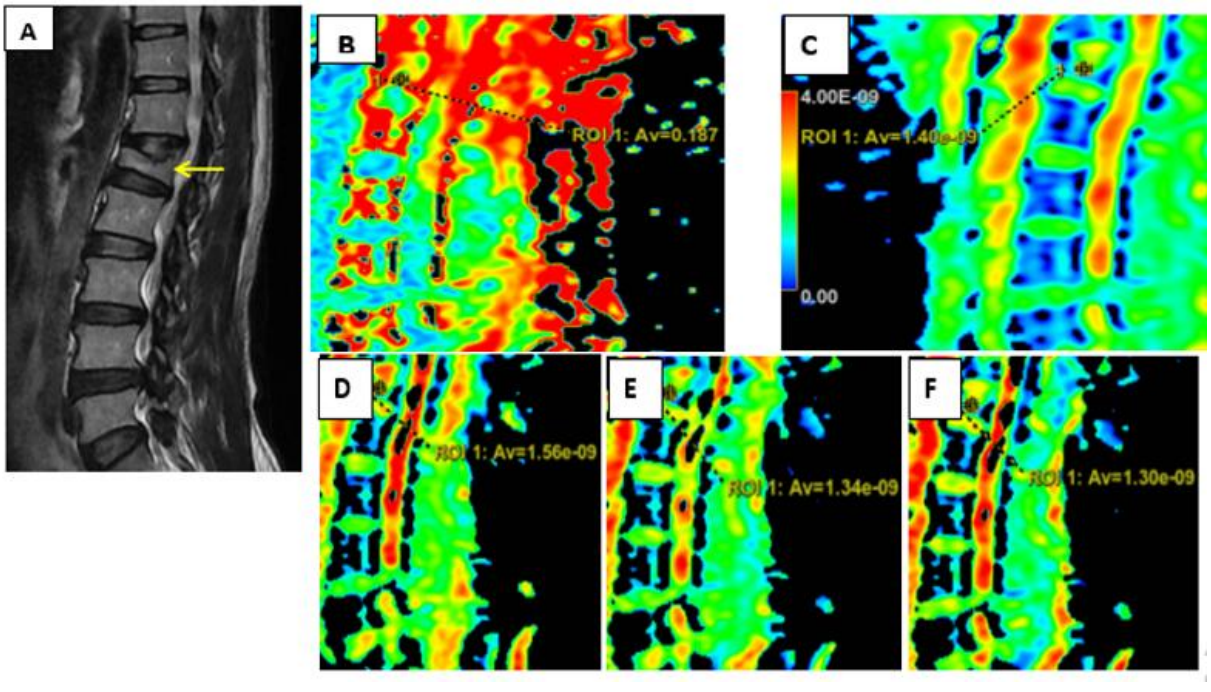

Figure (2): (A-F images): A 50-year-old male patient, he has a history of trauma. (A) Sagittal T2-weighted MR image acquired at 1.5 T shows decreased height of L1 vertebral body (yellow arrow), (B) Sagittal color coded FA map image shows decreased FA value at the level of vertebral fracture (0.187), (C) Sagittal color coded ADC map image shows increased ADC value at the level of vertebral fracture (1.40), and (D, E& F) Sagittal color coded diffusion coefficient images at (X,Y,Z) with increased MD (1.40) Findings consistent with benign traumatic vertebral collapse.

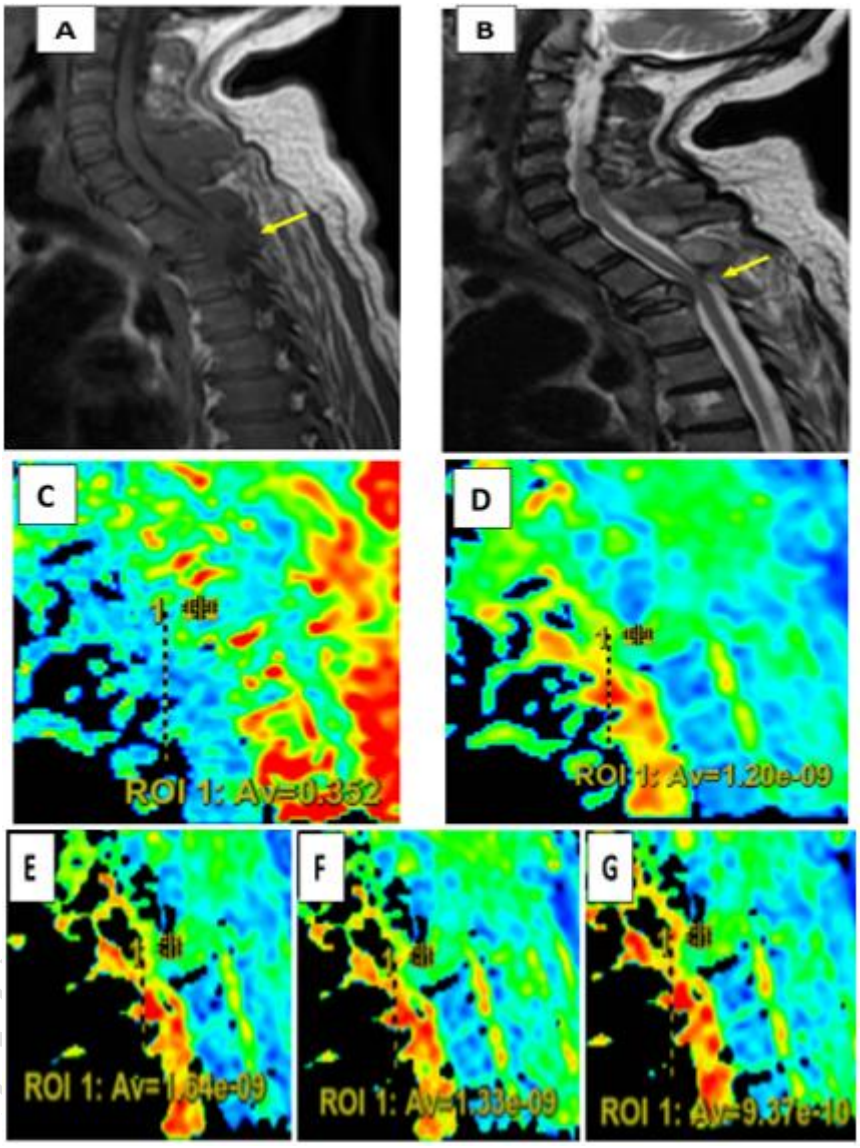

Figure (3): (A-G images): A 60-year-old male patient, he has a history of lung cancer. (A) Sagittal T1-weighted MR image and (B) Sagittal T2-weighted MR image acquired at 1.5 T show collapse and low signal intensity of D3 vertebral body (yellow arrows) with retro-pulsed fragment compressing the thecal sac, (C) Sagittal color coded FA map image shows decreased FA value at the level of vertebral fracture (0.352), (D) Sagittal color coded ADC map image shows increased ADC value at the level of vertebral fracture (1.20), and (E, F& G) Sagittal color coded diffusion coefficient images at

(X,Y,Z) with increased MD (1.3)….Findings consistent with malignant metastatic vertebral collapse.

According to ROC analysis for detectingspecificity and sensitivity of FA, ADC and mean diffusivity quantitative analysis of DTI MRI to differentiate between malignant and benign VCFs in cases group, we can see that the ROC for FA gives AUC 0.886 while ADC gives AUC 0.886 and MD gives AUC 0.922,with specificity and sensitivity of FA 85.71% and 93.75%respectively,while specificity andsensitivity of ADC 92.86% and87.50% respectively and specificity and sensitivity of MD 92.86%and 87.50% respectively as shown in **(Table 6)**and **(Figure 4).**

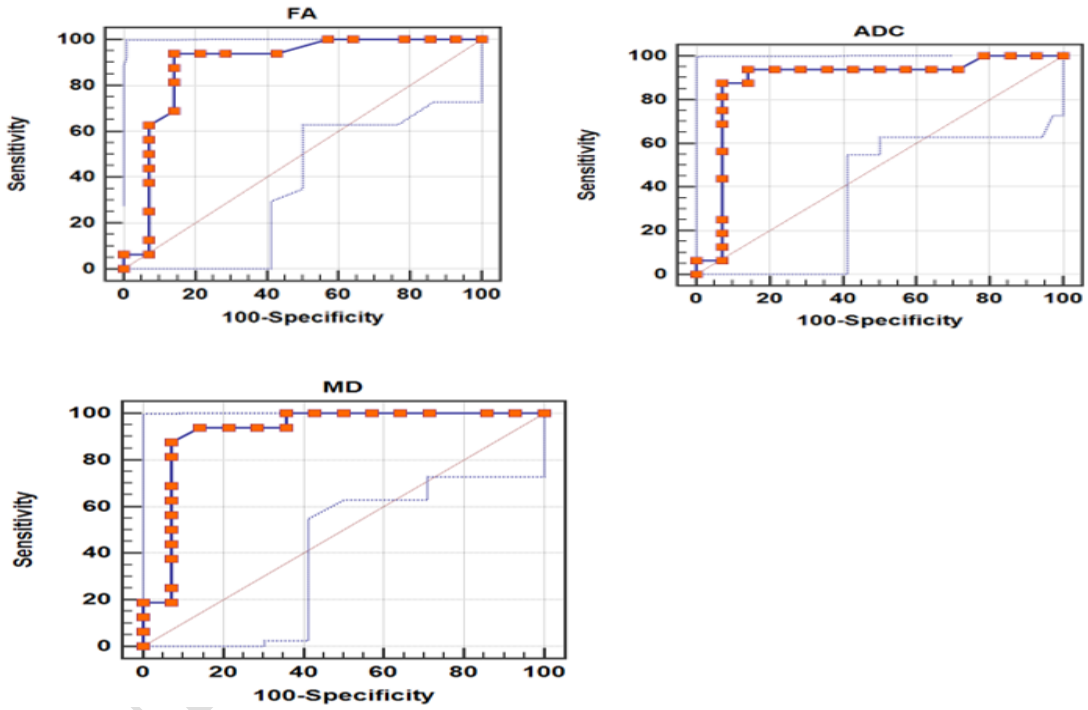

Figure (4): ROC curve between benign and malignant vertebral fractures according to FA, ADC, and MD.

Discussion

Up to 10% of individuals with initial neoplasms develop metastatic disease to the spine. However, up to one-third of VCFs in individuals with malignancies are predicted to be

benign.Vertebral fractures continue to be difficult to distinguish as benign or malignant, despite the significant advancements in diagnostic imaging in recent years. Understanding the etiology of vertebral fractures is necessary for their proper management[13].

The differentiation of an osteoporotic or malignant fracture origin based on SI criteria is challenging,even though MRI is the most useful tool for evaluating and characterizing vertebral fractures in clinical practice. Morphologic criteria for differentiation have been established; nevertheless, they may not be adequate to make a definitive diagnosis. [14].

DTIis aneffective technique for the non-invasive structural characterization of multiple anisotropic tissues. This method involves estimation of the within-voxel diffusion tensor using a sequence ofdiffusion-weighted imaging images. The eigenvectors and eigenvalues provide information along three orthogonal directions as regard the effective diffusivity once the tensor is estimated[15].

This study aimed toexamine the diagnostic accuracy of magnetic resonance diffusion tensor imaging (MR-DTI) in differentiating benign from malignant VCFs. It was carried out on 30 cases with vertebral fractures and a control group of 30 individuals.

Among the 30 studied patientswith vertebral fractures, 73.3% of them were males and the remaining 26.67% were females, with an age range from 32 to 79 years old and a mean of 56.333 ± 12.491 years.

Schousboe[16]stated in their study that under the age of 50-55, the incidence of vertebral fracture is significantly greater in males than in females, with higher risk among females after the age of 60 and substantially so after the age of 70. The incidence of clinical vertebral fracture in males increases somewhat after age 70, and significantly after age 80.

According to the etiology of vertebral fractures, it was trauma, osteoporosis, multiple myloma, metastases, lymphoma and meningioma with trauma and multiple myloma being the most common causes in 26.67% of the patients for each of them.

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Oztekin, et al[17]found that in the elderly, benign osteoporotic VCFs are prevalent. Metastases to the vertebrae are also prevalent, occurring in 5% to 10% of all cancer cases, especially cases with primary prostate, breast, lung, and uterine tumors, in addition to those with lymphoma ormultiple myeloma.

Alexandru and So[18]reported that neurological abnormalities are uncommon in people with VCFs who have not had significant trauma, although they may have significant functional impairment.

In the currenttrial, the most prevalent clinical manifestation among the studied 30 patients was back pain which was found in 70% of the patients.

The most prevalentregion of VCFswas the lumbar region (48.57%) while the cervical and sacral regions was the least injured (5.71%) for each.**Kaur, etal**[19]found that the lumbar region had the maximum vertebral lesions in 45.69% of the studied patients.

Many studies had evaluated the diagnostic performance of conventional MRI in diagnosis of malignant compressed vertebrae depending on different MRI findings.

In our study, conventional MRI revealed loss of height of all the examined fractured vertebral bodies in 30 patients (100%), followed by abnormal SI of BM, paravertebral soft tissue, expanded post vertebral contour, abnormal posterior element signal, and spinal cord compression. Lesions in other vertebrae were found in 12 patients (40.00%).

Regarding DTI MR imaging, quantitative assessment was performed in all the fractured vertebral bodies in the studied patients using FA, ADC and MD parameters and compared to those of the normal vertebra in the control group.

ADCis expressed in mm^2 /s; itquantitatively expresses the free water molecules'diffusion in thetissue's extracellular space. Variations in ADC values are related to the diffusion intensity in a specific region[20].

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In the present trial, the mean ADC value of benign fractures (1.579 ±0.368) are generally greater than that of malignant fractures (0.884±0.253) caused by tumor infiltration. The ADC values of both types of lesions are significantly greater than the ADC of normal vertebral BM (0.291±0.050).

Otherresearches have also reported a higher values of the ADC in cases with benign vertebral fractures than malignant fractures and both higher than the ADC of normal vertebral BM. The findings of our research are quite similar to **Wonglaksanapimon, et al.**[(21)]study, where they assessed32 benign compression fractures and7 malignant VCFs. The ADC value of malignant VCFsshowed higher significance compared to normal vertebral bodies ($p < 0.001$), but less values compared to benign VCFs($p < 0.001$).

While **Zhou, et al**[(22)]demonstrate atypically low ADC values for both lesion types.The pathophysiological features that lead to the documented ADC discrepancies of vertebral lesions are not yet fully understood. A probable explanation for the higher ADC in osteoporotic fractures is the trabecular structuredisruption and the presence of BM edema. However, in malignant lesions, the increased cellular density of tumor tissue is thought to limit molecular diffusion, resulting in lower ADCs. [(23)].

The ADCs of both benign and malignant lesions are significantly elevated in comparison to normal BM. This may be due to the fact that both types of lesion include only extremely low-fat fractions (<15%). As a result, diffusion tortuosity is drastically decreased in vertebral lesions, which is represented by higher diffusion coefficients. [(24)].

in this research, FA is an additional rotationally invariant parameter which is employed to describe anisotropic diffusion ratio. The value of FA is unitless as it is a ratio of diffusion coefficients, it ranges from 0 to 1, where 1 represents extremely anisotropic diffusion and0 represents isotropic diffusion. Every voxel undergoes the FA calculation, and the findings can be viewed as anisotropy maps[(25)].

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the FA value in benign vertebral fracture (0.253±0.114) in the patients group was significantly lower than the FA value (0.419±0.094) in malignant vertebral fracture compared to the mean FA in control group (0.807±0.066) ($p<0.001$).

So, the malignant vertebral BM affection had significantly higherFA compared to benign lesions. This is due tolow anisotropyin benign lesionand a moderate/high anisotropy grade of the malignant bone infiltration. The origin of anisotropy in malignancy can be linked to malignancy-induced damage to the normal cellular structure; thus, diminishing the diffusion directions of water molecules in the tumor. The fibrous connective tissue that makes up the majority of benign diseases is quite similar to isotropic diffusion [(26)].

In the study of **Razek and Sherif[(27)]**, the malignant VCFs of both readers (0.55 ± 0.2 and 0.52 ± 0.1) had significantly greater FAcompared to the benign VCFs(0.26 ± 0.1 and 0.28 ± 0.1) ($P = 0.001$) with excellent inter-reader agreement using FA between both readers ($K = 0.86$).

MD measures the totaldiffusion amount in a voxel orsample. MD representsthe density of the membrane, and is more sensitive for edema,cellularity, and necrotic alterations[(28)].

In the presentresearch, the MD value in benign VCFs(1.605±0.363) was significantlyhigher than the MD value (0.878±0.242) in malignant VCFscompared to the MD value in control group (0.262±0.065) ($p <0.001$).

The high malignant cells'cellularity that interfere with extracellular fluiddiffusion and free water in the necrotic area with benign lesions causesthe lower MD in malignant collapsed vertebrae compared to benign collapsed vertebrae [(29)].

Razek and sherif et al [(27)] reported that MD was significantly lowerin malignant (0.74 ± 0.2 and 0.78 ± 0.2 × 10^{-3} mm^2/s) compared to benign compressed vertebrae (1.67 + 0.3 and 1.63 ± 0.3 × 10^{-3} mm^2/s) ($P = 0.001$), with excellent inter-reader agreement using MD between both readers ($K = 0.91$).

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In our study, we reported higher sensitivity and specificity of fractional anisotropy (93.75% and 85.71%) than those of ADC (87.5% and 92.86%) and MD (87.5% and 92.86%) with cutoff values 0.28, 1.04 and 1.01 for FA, ADC, and MD respectively.

The majority of research reveal a degree of overlap between the ADCs related to malignantor osteoporotic lesions. However, by defining a threshold for ADC, many cases could be classified successfully; the statistical performance ofa such classification could be described by thedifferentiation specificity and sensitivity. **Wonglaksanapimon, et al**[21]reported ADC sensitivity of 85.7%, specificity of 90.6%, accuracy of 89.7% and < 0.89 ADC threshold.

Abo Dewan, et al[30]performed their study on 96 patients to distinguish between malignant and benign compressed vertebra with resulting ADC sensitivity of 95.1%, specificity of 92.7%, accuracy of 93.8% and < 1.21 ADC threshold.

There was no enough research to compare our results mainly the role of FA and MD in differentiating benign form malignant vertebral collapse; The existing research on the efficacy of spinal DTI have focused solely on the neurological elements [26, 31]. However, this gives our research strength and distinction.

Limitations:We includeddifferent malignant pathologies,also the sample size was relatively small. In addition, we included cases with malignant and benign causes of VCFsignoring the specific pathology that miss more specific and reliable results.

Conclusion: DTI with its quantitative indicators is a valuable tool in differentiating malignant from benign compressed vertebrae when compared to conventional MRI. FA values in benign vertebral fracture were significantly less than the FA values in malignant vertebral fracture. ADC & MD values in benign vertebral fracture were significantly higher than the ADC&MD values in malignant vertebral fracture. FA is more sensitive and accurate in differentiating benign frommalignantVCFs.The use of DTI in the routine investigation

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ofvertebral fractures along with MRI to distinguish malignant from benign VCFs is recommended.

List of abbreviations:

ADC: Apparent diffusion coefficient

BM: Bone marrow

DTI: Diffusion tensor imaging

EPI: Echo planar imaging

FA: Fractional anisotropy

FOV: Field of view

MD: Mean diffusivity

MR-DTI: Magnetic resonance diffusion tensor imaging

MRI: Magnetic resonance imaging

SI: Signal intensity

T1WFSE: T1 weighted fast-spin-echo sequence

T2WFSE: T2 weighted fast-spin-echo sequence

VCFs: Vertebral compression fractures

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Tables:

Table (1):Distribution of the studied cases according to age and sex (n= 60).

		Group		test	P-value
		Patient	**Control**		
Gender	**Male**	22 (73.33 %)	15 (50 %)	**X^2:**3.455	0.063
	Female	8 (26.67 %)	12 (50 %)		
	Total	30 (100 %)	30 (100 %)		
Age	**Range**	32-79	34-70	**t**: 0.109	0.914
	Mean ±SD	56.333±12.491	56.000±11.265		

Data is presented as mean± SD, range or frequency (%). $\chi 2$: chi-square test, p value: probability for Chi square test for association between patients and control group, t: T-Student test.

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Table (2): Distribution of the patients according to clinical presentation (n=30).

Clinical presentation	N (%)
Asymptomatic	9 (30 %)
Symptomatic	21 (70 %)
→ Back Pain	21 (70 %)
→ Limitation of movement	6 (20 %)

Data is presented as frequency (%).N.B: one patient may have two symptoms.

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Table (3): Etiology of vertebral fractures in the studied patients (n=30).

Etiology of vertebral fractures	N (%)
Trauma	8 (26.67 %)
Multiple Myloma	8 (26.67 %)
Osteoporosis	6 (20 %)
Mets	6 (20 %)
Lymphoma	1 (3.33 %)
Meningioma	1 (3.33 %)

Data is presented as frequency (%).

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Table (4): The site of vertebral fractures in the studied patients (n=30) according to MRI examination, while in control group (n=30), it was at a prospective chosen region.

Level	Group		Test	P-value
	Patient	Control		
Cervical	3 (8.57 %)	10 (33.33 %)	**X^2:**8.381	0.039*
Dorsal	13 (37.14 %)	10 (33.33 %)		
Lumbar	17 (48.57 %)	10 (33.33 %)		
Sacral	2 (5.71 %)	0 (0 %)		

Data is presented as frequency (%).$\chi 2$: chi-square test, p value: probability for Chi square test for association between patients and control group.N.B: more than one fracture site could be seen in one patient. *: significant p value (< 0.05).

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Table (5): Comparison of FA, ADCe-09 mm2/s & MDe-09 mm2/s parameter between patients and control group.

		Subgroups			ANOVA		TUKEY'S Test		
		Benign	Malignant	Control	F	P-value	B&M	B&C	M&C
FA	Range	0.14 - 0.6	0.23 - 0.63	0.7 - 0.9	231.208	<0.001*	<0.001*	<0.001*	<0.001*
	Mean ±SD	0.253 ± 0.114	0.419 ± 0.094	0.807 ± 0.066					
ADC	Range	0.7 - 2.14	0.64 - 1.7	0.21 - 0.37	165.883	<0.001*	<0.001*	<0.001*	<0.001*
	Mean ±SD	1.579 ± 0.368	0.884 ± 0.253	0.291 ± 0.050					
MD	Range	0.7 - 2.15	0.55 - 1.6	0.14 - 0.35	184.944	<0.001*	<0.001*	<0.001*	<0.001*
	Mean ±SD	1.605 ± 0.363	0.878 ± 0.242	0.262 ± 0.065					

Data is presented as mean± SD and range. F: F for ANOVA test, p value: probability for ANOVA test for association between patients and control group;*: significant p value (< 0.05).FA: Fractional anisotropy, MD: Mean diffusivity, ADC: Apparent diffusion coefficient,

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Table (6): Analysis of the diagnostic ability of FA, ADC& MD to differentiate between benign and malignant vertebral fractures in patients' group.

ROC curve between Benign and Malignant fractures in Patients							
	Cut off	**Sens.**	**Spec.**	**PPV**	**NPV**	**AUC**	**P-value**
FA	>0.28	93.75	85.71	88.2	92.3	0.886	<0.001*
ADC	≤1.04	87.50	92.86	93.3	86.7	0.886	<0.001*
MD	≤1.01	87.50	92.86	93.3	86.7	0.922	<0.001*

Sens.: sensitivity, spec.: specificity, PPV: positive predictive value, NPV: negative predictive value, AUC: area under the curve, FA: Fractional anisotropy, MD: Mean diffusivity, ADC: Apparent diffusion coefficient, p value: probability for independent samples t-test for association between patients and control group;*: significant p value (< 0.05).

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