Diffusion Weighted Magnetic Resonance Imaging in Diffuse and Focal Vertebral Bone Marrow Lesions Using Apparent Diffusion Coefficient (ADC) Mapping as a Quantitative Assessment Tool

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Abstract

Background: Routine magnetic resonance imaging MRI is highly sensitive in detecting bone marrow alterations; however, it is of limited specificity in the evaluation of the causes of these alterations. Diffusion Weighted Imaging (DWI) is an imaging technique which probes the structure of a biologic tissue. The contrast achieved with this technique together with measurement of the apparent diffusion coefficient ADC values are useful complementary MRI tools and can be used for non-invasive tissue characterization and therefore reaching a more specific diagnosis.

Aim of Work: The aim of this study is to determine the value of both qualitative and quantitative assessment of DWI in differentiation between different vertebral lesions and to determine cut off ADC value between benign and malignant lesions.

Patients and Methods: This is a prospective study carried out in Radio-Diagnosis Department, Faculty of Medicine, Cairo University between August 2014 and February 2016 for patients diagnosed with or suspected to have vertebral lesion of any etiology. A total number of 40 patients (22 males and 18 females) with age range 2-88 (average 49).

The MRI sequences obtained were sagittal T1WI, T2WI, STIR and axial T1WI, T2WI & DWI ($\pm$ post contrast images in some patients). Bone marrow signal intensity was qualitatively analyzed by visually comparing its signal intensity with the signal intensity of the intervertebral disc, fat and muscle tissue on T1-weighted images. Hyperintense lesions on the DWI were identified and ADC values were automatically calculated using the software provided by the MR scanner manufacturer (Diffusion Calculation: Philips Medical Systems) and the ADC quantitative parameter was expressed in: 10^{-3} mm^2/s.

Results: Our study included 40 patients who were diagnosed with or suspected to have vertebral lesion of any etiology. Qualitative evaluation of the lesion contrast in diffusion-weighted MRI of the vertebral column has been shown to be valuable for the differentiation of lesion etiology; however, visual assessment of high signal intensity was not specific for malignancy.

On the other hand the quantitative assessment by measuring the ADC value was able to distinguish benign from malignant high signal intensity on DWI.

In our study, infiltrated neoplastic marrow as well as hypercellular red marrow had higher ADC values than normal marrow while inflammatory lesions and hemangiomas had the highest ADC values.

Conclusion: Diffusion weighted MRI is a reliable tool in characterization of different vertebral bone marrow abnormalities. The routine MRI protocol of spine examinations could be modified to include DWI as a cost effective substitute for the gadolinium enhanced scan especially in patients with contraindication for contrast administration.

Key Words: DWI – Vertebral lesions – Bone marrow – ADC – Malignant lesions.

Introduction

MAGNETIC Resonance Imaging (MRI) is the mainstay of diagnosis, staging and follow-up of much musculoskeletal pathology. Diffusion-weighted magnetic resonance imaging (DWI) is a recent addition to the MR sequences conventionally employed [1].

DWI provides qualitative and quantitative functional information concerning the microscopic movements of water at the cellular level. The signal intensity of DWI relies on the stochastic Brownian motion, or self diffusion of water molecules at a microscopic level within tissues. Extracellular water has more freedom, or is less impeded in its motion, in comparison to intracellular water molecules, which are limited in their motion by intracellular organelles, macromolecules and cell membranes. Areas with higher cellularity (and therefore more intracellular components and cell membranes)

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will demonstrate impeded molecular water mobility [1].

Diffusion-weighted MRI has been used successfully in the Central Nervous System (CNS), especially in the diagnosis of acute stroke, but also in distinguishing different components of brain tumors. Diffusion measurements of tumors outside the brain have also been reported [2].

DWI is a fast MRI sequence, which offers without any contrast media injection, assessment of various types of spine vertebral and discal lesions [3].

In cases of bone marrow infection; while benign in nature, osteomyelitis can cause hyperintensity on DWI which may mimic malignancy [4].

In diffusion-weighted images of the spine, malignant lesions appear predominantly hyperintense. Hypointense signal of malignant vertebral lesions, may be explained either by lesions irradiated before imaging or by sclerotic metastases with very low water content [5].

DWI did not show high signal intensity at the site of endplate abnormalities in patients with degenerative changes [6].

Diffusion weighted imaging is also useful in post-treatment follow-up of bone marrow neoplastic lesions. When bone marrow disease is treated successfully, the tumour cell death results in increased water diffusivity manifested as increased ADC values [1].

Aim of the work: The aim of this study is to determine the value of both qualitative and quantitative assessment of DWI in differentiation between different vertebral lesions and to determine cut off ADC value between benign and malignant lesions.

Patients and Methods

This is a prospective study carried out in Radio-Diagnosis Department, Faculty of Medicine, Cairo University between August 2014 and February 2016 for patients diagnosed with or suspected to have vertebral lesion of any etiology. Informed consent was obtained for this ethics committee approved study.

A total number of 40 patients (22 males and 18 females) with age range 2-88 (average 49).

Inclusion criteria:
• Patients diagnosed with vertebral lesion or vertebral bone marrow abnormality.

• Patients suspected to have vertebral lesion.

Exclusion criteria:
• Patients with pacemaker.
• Patients with claustrophobia.

Patients were subjected to the following:
1- *Clinical assessment:* Short medical history was taken from out patients, however; more detailed clinical and laboratory data were obtained from in-patients.

2- *Radiological investigations:*
  A- *MRI examination:* All patients were subjected to MRI examination. Some patients received IV contrast "gadolinium D.T.P.A".

  B- Plain X-ray, CT, or bone scan were done for some of the patients.

  C- Pathological examination results were available in some cases form which biopsy was taken during our study.

MR imaging technique:
• Imaging was performed using a standard 1.5 Tesla unit (Intera and Achieva, Philips).

• A sense spine coil was used.

A- *Routine MRI sequences of spine:*
  • Sagittal T1WI, T2WI & STIR.

  • Axial T1WI & T2WI.

  • Contrast enhanced images (in some patients) after manual intravenous administration of 0.1mmol/kg of gadolinium-DTPA.

B- *DWI of spine:*
DWI was performed with free breathing and inversion recovery single-shot spin-echo echo-planar sequences (TR/TE, 9000/68; number of slices, 12; slice thickness, 5mm; gap, 0mm; flip angle, 90º; FOV, 300mm^2). We applied 3 diffusion-sensitizing gradients with b-values of 0, 50 and 800s/mm^2. The total imaging time was 6:09min.

Image analysis:
All images were loaded to a workstation (Philips Medical Systems). Bone marrow evaluation and image interpretation were performed.

A- *Qualitative analysis:*
Bone marrow signal intensity was qualitatively analyzed by visually comparing its signal intensity

with the signal intensity of the non-degenerated intervertebral disc, subcutaneous fat and muscle tissue depicted on T1-weighted images. For MRI interpretation, we used previously established diagnostic criteria for vertebral bone marrow evaluation.

B- *Quantitative analysis:*

The radiologist quantitatively evaluated the bone marrow signal intensity by performing measurements in Regions of Interest (ROI). Hyperintense lesions on the DWI (with a high *b*-value "*b* 800") which correspond to the lesions with abnormal signal intensity changes on the T1 & T2 weighted MR images were identified and the ROI was manually drawn within the confines of the hyperintensity.

The ROI was lesion-size-dependent in localized discrete lesions, but in diffuse vertebral marrow lesions it was drawn as large as possible placed in the antrocentral aspect of vertebral body to avoid vertebral end plate degenerative changes and basivertebral vein plexus.

In addition the ADC value of normal/normal appearing vertebral bodies were measured by placing ROI at the center of the vertebral bodies.

The regions of interest varied between 5 and 15mm in diameter. In each patient at least 3 ROI were applied.

ADC values were automatically calculated using the software provided by the MR scanner manufacturer (Diffusion Calculation: Philips Medical Systems) and the ADC quantitative parameter was expressed in: 10^{-3} mm^2/s. The average ADC value of the three regions of interest of each patient was calculated and recorded. The final diagnosis which was made on the basis of biopsy results or results of clinical and radiologic follow-up was used as the "gold standard" to classify the vertebral marrow lesions.

Results

A total number of 40 patients (22 males and 18 females) with age range 2-88 (average 49) diagnosed with or suspected to have vertebral lesion of any etiology were radiologically evaluated.

The vertebral bone marrow abnormalities classification:

The patients included in the study were 21 of benign nature and 19 malignant vertebral marrow infiltrative lesions (Table 1). This diagnosis is based on clinical, radiological and histo-pathological data. The 21 patients with benign marrow lesions included 9 patients with inflammatory/infectious spondylitis or spondylodiscitis, 4 patients with benign neoplastic marrow lesions, 3 patients with diffuse yellow to red marrow reconversion and 5 patients with degenerative marrow changes.

On the other hand the 19 patients with established malignant multifocal or infiltrative vertebral marrow lesions included metastatic lesions (n=17) lymphomatous infiltration (n=1) and multiple myeloma (n=1).

Table (1): Classification of the vertebral bone marrow abnormalities.

Group	No. of patients
Inflammatory	9
Benign neoplastic lesion	4
Malignant neoplastic lesion	19
Red marrow	3
Degenerative	5

Inflammatory lesions:

On DWIs, all lesions in the inflammatory group revealed high signal intensity. The mean ADC value of pyogenic spondylodiscitis was high (mean; 1.454 X 10^{-3} mm^2/s, SD ±0.16 X 10^{-3} mm^2/s) while TB spondylodiscitis were of lower ADC values (mean; 1.191 X 10^{-3} mm^2/s, SD ±0.29 X10^{-3} mm^2/s) (Table 2).

Table (2): DWI signal and ADC values in inflammatory lesions.

Diagnosis	DWI signal	ADC value (X 10^{-3} mm^2/s)	
		Range	Mean ± SD
Pyogenic spondylodiscitis	High	1.369-1.690	1.454±0.16
TB spondylodiscitis	High	0.902-1.564	1.191±0.29

Benign Neoplastic lesions:

A total of four cases with benign neoplastic vertebral lesions were found: Three cases with hemangioma and one case with osteoblastoma.

On DWIs, hemangiomas revealed low signal intensity while the osteoblastoma revealed high signal intensity. The mean ADC value of the hemangioma was high (mean; 1.406 X 10^{-3} mm^2/s, SD ±0.13 X 10^{-3} mm^2/s) while osteoblastoma was of lower ADC value (0.818 X 10^{-3} mm^2/s) (Table 3).

Table (3): DWI signal and ADC values in benign neoplastic lesions.

Diagnosis	DWI signal	ADC value ($\times 10^{-3}$ mm^2/s)	
		Range	Mean ± SD
Hemangioma	Low	1.254-1.512	1.406±0.13
Osteoblastoma	High	0.818	

Malignant Neoplastic lesions:

A total of nineteen cases with malignant vertebral lesions were found: Seventeen patients with metastatic lesions, a case of lymphoma and a case of multiple myeloma. The case of lymphoma and one of the patients with metastasis were presenting for follow-up after receiving therapy.

On DWIs, eighteen malignant lesions revealed high signal intensity while the case of multiple myeloma revealed low signal intensity. The mean ADC value of the non treated malignant lesions was (mean; 0.982×10^{-3} mm^2/s, SD ±0.17 $\times 10^{-3}$ mm^2/s) while the two lesions under therapy were of higher ADC values (1.612 & 1.483×10^{-3} mm^2/s) (Table 4).

Table (4): DWI signal and ADC values in malignant neoplastic lesions.

Diagnosis	DWI signal	No.	ADC value ($\times 10^{-3}$ mm^2/s)		No.
			Range	Mean ± SD	
Metastasis:					
Pretherapy.	High	16	0.624-1.237	0.982±0.17	16
Post therapy.	High	1		1.612	1
Multiple myeloma.	Low	1		0.975	1
Lymphoma:					
Post therapy.	High	1		1.483	1

Red marrow (persistent/reconversion):

On DWIs, one case was of high signal intensity while the other two cases were of low signal intensity. The mean ADC value was (mean; 0.613×10^{-3} mm^2/s, SD ±0.08 $\times 10^{-3}$ mm^2/s) (Table 5).

Table (5): DWI signal and ADC values in the red marrow group.

Diagnosis	DWI signal	No.	ADC value ($\times 10^{-3}$ mm^2/s)	
			Range	Mean ± SD
Red marrow	High	1	0.544-0.711	0.613±0.08
	Low	2		

Degenerative changes of the bone marrow:

On DWIs, degenerative lesions revealed low signal intensity. The mean ADC value was (mean; 0.569×10^{-3} mm^2/s, SD ±0.06 $\times 10^{-3}$ mm^2/s) (Table 6).

Table (6): DWI signal and ADC values in the degenerative group.

Diagnosis	DWI signal	ADC value ($\times 10^{-3}$ mm^2/s)	
		Range	Mean ± SD
MODIC I	Low	0.525-0.664	0.569±0.06
MODIC II	Low		

Summary of ADC values of the different groups:

Table (7): DWI signal and ADC values of the different groups.

Diagnosis	DWI signal	ADC value ($\times 10^{-3}$ mm^2/s)	
		Range	Mean ± SD
Pyogenic spondylodiscitis	High	1.369-1.690	1.454±0.16
TB spondylodiscitis	High	0.902-1.564	1.191±0.29
Hemangioma	Low	1.254-1.512	1.406±0.13
Malignant	High	0.624-1.237	0.982±0.17
Red marrow	High	0.544-0.711	0.613±0.08
	Low		
Degenerative changes	Low	0.525-0.664	0.569±0.06

The ADC values recorded from the automatically created ADC maps (Table 7) differed significantly (p-value <0.001, highly significant) between malignant (mean, 0.982×10^{-3} mm^2/s; SD ±0.17 $\times 10^{-3}$ mm^2/s) and the following benign marrow entities; inflammatory pyogenic marrow lesions (mean, $1.454\pm0.322 \times 10^{-2}$ mm^2/s; SD ±0.16 $\times 10^{-3}$ mm^2/s) and the degenerative marrow changes (mean, 0.569×10^{-3} mm^2/s; SD ±0.06 $\times 10^{-3}$ mm^2/s). ADC values of malignant lesions also differed significantly (p-value 0.002, significant) from the hemangiomas (mean, $1.406\pm0.13 \times 10^{-3}$ mm^2/s; SD ±0.16 $\times 10^{-3}$ mm^2/s).

There was an overlap between the ADC values of malignant lesions and TB spondylodiscitis (mean, 1.191×10^{-3} mm^2/s; SD ±0.29 $\times 10^{-3}$ mm^2/s), yet with a statistically significant difference (p-value 0.034, significant) in their ADC values. An overlap between the ADC values of malignant lesions and the red marrow (mean, 0.613×10^{-3} mm^2/s; SD ±0.08 $\times 10^{-3}$ mm^2/s) was also detected, yet with a statistically significant difference (p-value 0.002, significant) in their ADC values.

The ADC value of osteoblastoma (0.818×10^{-3} mm^2/s) was within the range of ADC values of the malignant bone marrow lesions.

The ADC values of post therapy neoplastic lesions "metastasis" 1.612×10^{-3} mm^2/s and "lymphoma" 1.483×10^{-3} mm^2/s were higher than those

of prethergy malignant lesions (mean, 0.982 X 10^{-3} mm^2/s; SD ±0.17 X 10^{-3} mm^2/s).

Receiver Operating Characteristics (ROC) curve was used to define the best cut off value of ADC (10^{-3} mm^2/sec) between benign and malignant lesions which was ≤1.237, with sensitivity of 100% specificity of 61.9% positive predictive value of 66.7, negative predictive value of 100% with diagnostic accuracy of 72%.
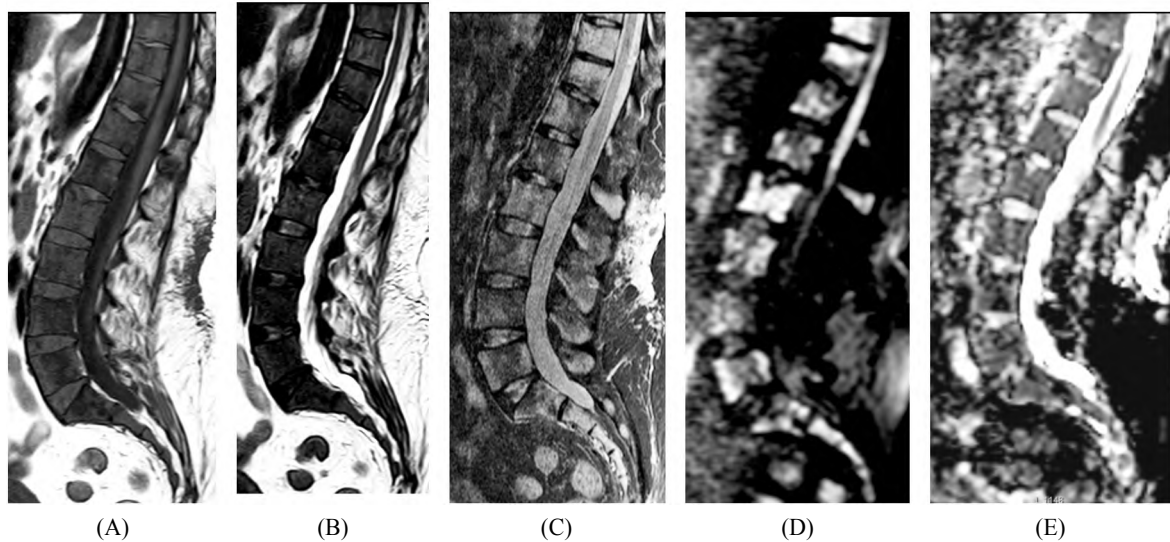

(A)   (B)   (C)   (D)   (E)

Fig. (1): 45 year old female known to have breast cancer presenting with back pain. MRI of the lumbosacral spine revealed multiple metastatic deposits: (A) T1, (B) T2, (C) STIR (D) DWI and (E) ADC sagittal images revealing diffuse alteration of the bone marrow signal eliciting low signal on both T1 & T2 WIs with multiple patchy areas of bright signal intensity on STIR images and patchy areas of restricted diffusion. ADC value: 1.061 X 10^{-3} mm^2/s.

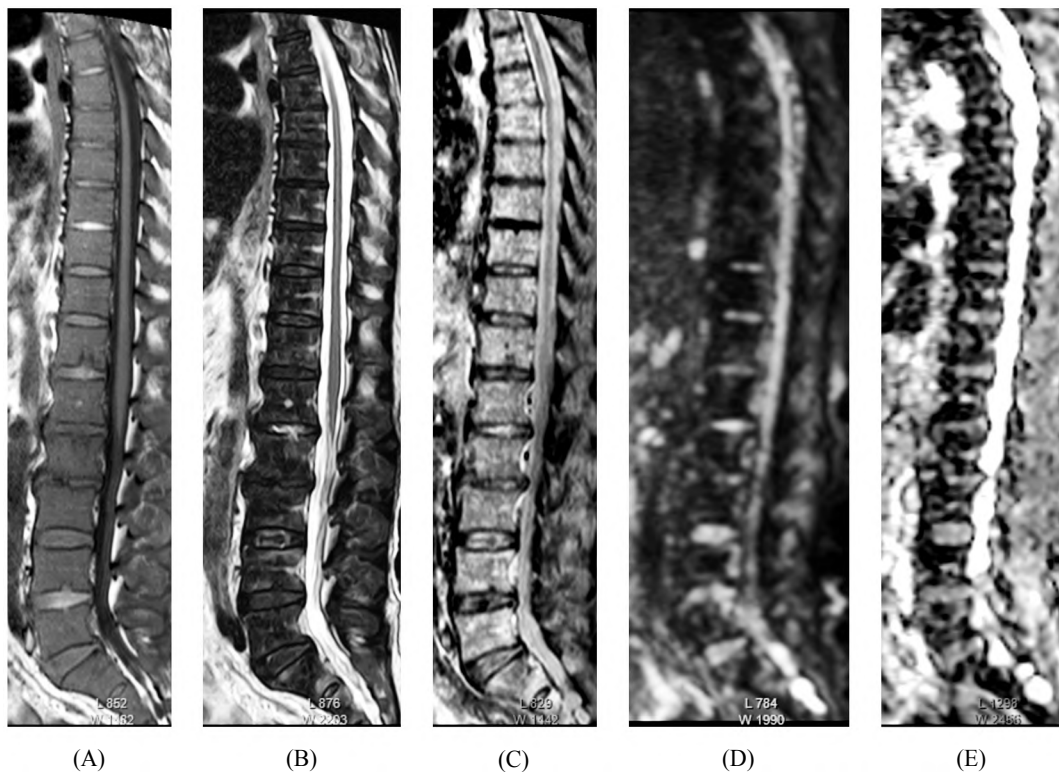(A)   (B)   (C)   (D)   (E)

Fig. (2): 64 year old male known to have multiple myeloma presenting with back pain. MRI of the dorsolumbar spine: (A) T1, (B) T2, (C) STIR (D) DWI and (E) ADC sagittal images of a case of multiple myeloma revealed diffuse alteration of the bone marrow signal of the lumbar vertebrae eliciting low signal on both T1 & T2 WIs and rather diffuse high signal intensity on STIR images with no areas of restricted diffusion noted. ADC value: 0.975 X 10^{-3} mm^2/s

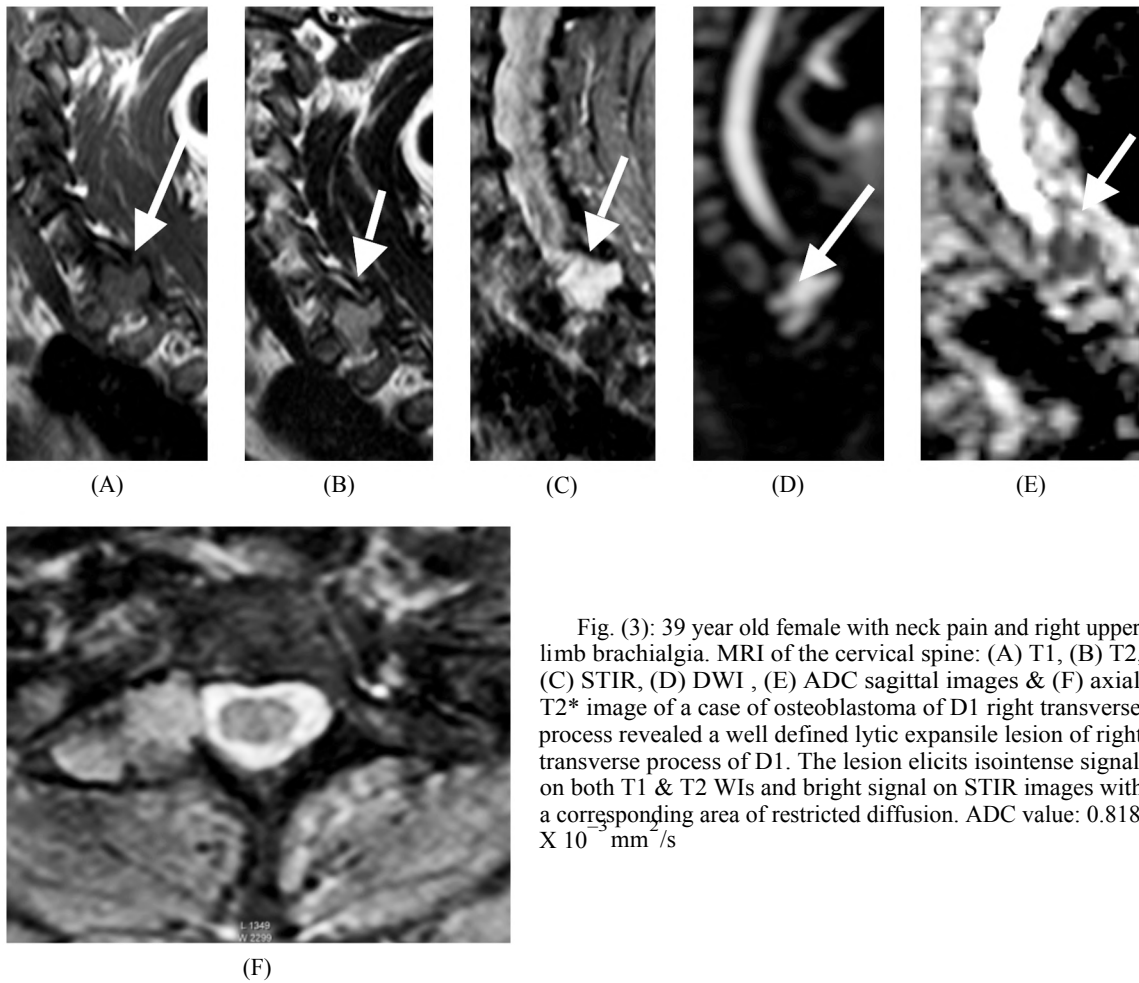(A)   (B)   (C)   (D)   (E)

(F)

Fig. (3): 39 year old female with neck pain and right upper limb brachialgia. MRI of the cervical spine: (A) T1, (B) T2, (C) STIR, (D) DWI , (E) ADC sagittal images & (F) axial T2* image of a case of osteoblastoma of D1 right transverse process revealed a well defined lytic expansile lesion of right transverse process of D1. The lesion elicits isointense signal on both T1 & T2 WIs and bright signal on STIR images with a corresponding area of restricted diffusion. ADC value: 0.818 X 10^{-3} mm^2/s

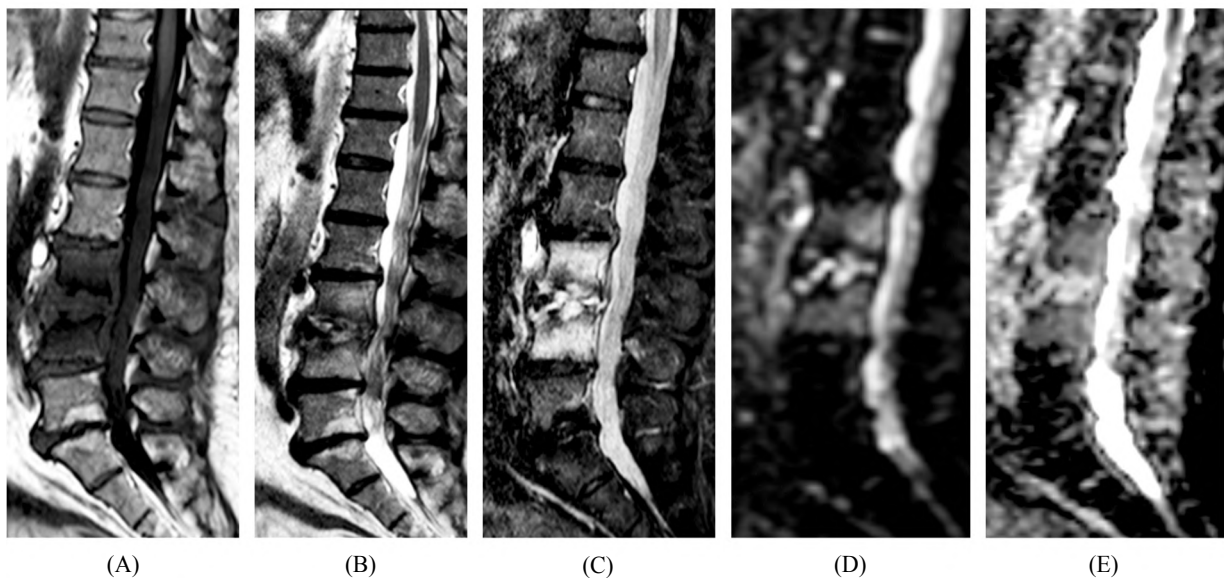(A)   (B)   (C)   (D)   (E)

Fig. (4): 60 year old male "prisoner" presenting with back pain. MRI of the lumbosacral spine: (A) T1, (B) T2, (C) STIR (D) DWI and (E) ADC sagittal images of a case of pyogenic spondylodiscitis. Sagittal T1-weighted image shows diffuse low signal intensity of L3 and L4 vertebrae. Sagittal T2-weighted image and sagittal STIR show corresponding high signal intensity of L3 & L4 vertebrae as well as the intervening L3/4 disc with diffusion restriction of L3 and L4 vertebrae and intervening disc. ADC value: 1.369 X 10^{-3} mm^2/s.

Statistical analysis:

Data were analyzed using Statistical Program for Social Science (SPSS) Version 20.0. Quantitative data were expressed as mean ± Standard Deviation (SD). Qualitative data were expressed as frequency and percentage.

The following tests were done:
- Independent-samples *t*-test of significance was used when comparing between two means.

- Chi-square (χ^2) test of significance was used in order to compare proportions between two qualitative parameters.

- Receiver Operating Characteristic (ROC curve) analysis was used to find out the overall predictivity of parameter and to find out the best cut-off value with detection of sensitivity and specificity at this cut-off value.

- Probability (*p*-value).
  - *p*-value <0.05 was considered significant.

  - *p*-value <0.001 was considered as highly significant.

  - *p*-value >0.05 was considered insignificant.

Discussion

Diffusion weighted MR sequences provide microscopic information to supplement the macroscopic information provided by conventional sequences. It is a non invasive imaging technique which is suitable for probing the physical structure of a biologic tissue at a microscopic level and it exploits the random, translational motion of water protons in a biologic tissue, which reflects the tissue specific diffusion capacity and can be used for tissue characterization.

In this study we found that visual assessment of high signal intensity on high *b*-value (800) was not specific for malignancy because inflammation and hyperactive hematopoietic marrow can result in a similar diffusion restriction, this was in agreement with Zidan et al., [7], Koh et al., [8] and Ballon et al., [9].

On the other hand the quantitative assessment by measuring the ADC value was able to distinguish benign from malignant high signal intensity on DWI. This was in agreement with Leeds et al., [10], Zhou et al., [11], Padhani et al., [12] & Zidan et al., [7], who highlighted the necessity of correlating high b-value DW images with corresponding ADC values.

Zidan et al., [7] stated that normal yellow marrow had the lowest ADC value and the infiltrated neoplastic marrow as well as hypercellular red marrow had higher ADC value, on the other hand the infective/inflammatory bone marrow lesion had the highest ADC value.

This was in agreement with our study which revealed that infiltrated neoplastic marrow as well as hypercellular red marrow had higher ADC values while inflammatory lesions and hemangiomas had the highest ADC values.

On the other hand, in agreement with Padhani et al., [12] & Zidan et al., [7] there was narrow signal intensity and ADC value difference between malignant and red marrow yet, the ADC value difference between the two entities was statistically significant with *p*-value 0.002.

Our study stated that the mean ADC value of pyogenic vertebral lesions was $1.45 \pm 0.16 \times 10^{-3}$ mm^2/sec and was significantly higher than that of malignant lesions ($0.98 \pm 0.17 \times 10^{-3}$ mm^2/sec) (*p* <0.001) with an absence of overlap.

In agreement with our study, Abo Dewan et al., [13] stated that the mean ADC value of pyogenic vertebral lesions was $1.71 \pm 0.12 \times 10^{-3}$ mm^2/sec and was significantly higher than that of malignant lesions ($0.75 \pm 0.23 \times 10^{-3}$ mm^2/sec) (*p*=0.007) with an absence of overlap. Taskin et al., [14] also stated that the mean ADC values of infectious lesions were $1.54 \pm 0.15 \times 10^{-3}$ mm^2/sec and were significantly higher than malignant lesions (*p*<0.0001). Also they reported only 2 of the 23 vertebral infectious lesions displayed ADC values overlapping with malignant lesions.

In contrast to our results Balliu et al., [15] and Fawzy et al., [16] stated that the ADC values of infectious lesions and malignant lesions coincided and therefore they could not differentiate them.

Our study revealed that the mean ADC value of the tuberculous lesions was $1.191 \pm 0.29 \times 10^{-3}$ mm^2/sec with an overlap between tuberculous and malignant lesions, yet with a statistically significant difference with that of malignant lesions (*p*=0.034).

Abo Dewan et al., [13] study revealed that the mean ADC value of the tuberculous lesions was $0.91 \pm 0.08 \times 10^{-3}$ mm^2/sec with a non-significant difference with that of malignant lesions (*p*=0.143) and the presence of an overlap between tuberculous and malignant lesions. Palle et al., [17] also found the mean ADC values of tuberculosis lesions to be

1.4×10^{-3} mm^2/sec and when they took this value as a cutoff in the discrimination of malignant lesions, they found 64.8% sensitivity, 75% specificity, and 74.5% positive predictive values. However, due to the fact that this ADC value displays values overlapping with the ADC values of metastatic vertebral lesions, they emphasized that the ADC values should be evaluated with the clinical history and routine MR findings. These results were quite similar to ours, but there were some limitations in this comparison since the number of tuberculous lesions in our study was small compared to Palle et al., [17].

Our study detected that DWIs can differentiate between atypical hemangioma and metastatic spine lesions. We found atypical and typical hemangiomas in our study expressing non restricted diffusion in the form of low signal on DWI, while the metastases showed restricted diffusion in the form of high signal in DWI and low signal in ADC maps. We found significantly low ADC values calculated in metastatic bony lesions compared with typical and atypical hemangioma. These differences were grossly apparent. In our results the mean ADC value of hemangiomas was found as 1.406×10^{-3} mm^2/sec. The mean ADC value of metastatic bony lesions was found as 0.982×10^{-3} mm^2/sec.

This was in agreement with Matrawy et al., [18] that stated that restricted diffusion was seen in metastasis while in hemangioma it shows no restriction, the mean ADC value of hemangiomas was found as 1.54×10^{-3} mm^2/sec and the mean ADC value of metastatic bony lesions was found as 0.83×10^{-3} mm^2/sec. Taskın et al., [14] also found that ADC values for atypical hemangiomas were between 1.94 and 2.82×10^{-3} mm^2/sec. With a mean ADC value of $1.80 \pm 0.37 \times 10^{-3}$ mm^2/sec, while the ADC values of malignant lesions were between 0.43 and 1.44×10^{-3} mm^2/sec with a mean ADC value of $0.94 \pm 0.34 \times 10^{-3}$ mm^2/sec. Also our results are in agreement with (Leeds et al., [10]) who reported that hemangiomas had ADC values higher than those of metastases because of the contribution of water molecules within the vascular spaces.

(Byun et al., [19]) have investigated the usefulness of DWI for the assessment of response to therapy. Affected vertebrae appeared hyperintense on DWI images prior to therapy. Interestingly, for patients who experienced clinical improvement, diseased vertebrae were hypointense to normal bone marrow on follow-up diffusion images acquired one month after therapy.

In this study two cases of malignant lesions under therapy were of hyperintense signal on DWIs, yet showing higher ADC values 1.612 and 1.483×10^{-3} mm^2/sec compared to range of untreated malignant cases $(0.624\text{-}1.237 \times 10^{-3}$ mm^2/sec).

This was in agreement with Khoo et al., [1] that stated that when bone marrow disease is treated successfully, the tumour cell death results in increased water diffusivity manifested as increased ADC values, yet there is some limitations in our study since the number of treated lesions in our study was small.

In the present study we recorded that the best cut off value of ADC $(10^{-3}$ mm^2/sec) between benign and malignant lesions was ≤ 1.237, with sensitivity of 100% specificity of 61.9% positive predictive value of 66.7%, negative predictive value of 100% with diagnostic accuracy of 72%. Other studies also defined an ADC threshold $(\times 10^{-3}$ mm^2/sec) for differentiating benign from malignant lesions; Fawzy et al., [16] recorded cut off value of ADC <1.15, Wonglaksanapimon et al., [20]<0.89, Ta̧skın et al., [14] <1.32, Sung et al., [21]<1.242, Geith et a.l, [22] <1.70, Abo Dewan et al., [13] <1.21 & Yehya et al., [23] <0.78.

Dallaudière et al., [3] stated that ADC values could also differentiate between axial active inflammatory lesions and degenerative end plate changes; mean ADC values were significantly different between axial active inflammatory lesions and degenerative changes $(p=0.0005)$, best ADC cut-off value was 0.58×10^{-3} mm^2/sec, this was in agreement with our study which shows highly significant statistical difference $(p\text{-value} <0.001)$ between causes of vertebral end plate abnormalities (degenerative and inflammatory) according to ADC with cut off value of ADC 0.664×10^{-3} mm^2/sec.

Eguchi et al., [6] also agreed with our study and showed hyperintensity of vertebral bone marrow on DWIs in all patients with spinal infections, but not in any patients with degenerative changes. Mean ADC values for infectious bone marrow were significantly higher than for normal and degenerative bone marrow.

Conclusion:

Diffusion weighted MRI is a reliable tool in characterization of different vertebral bone marrow abnormalities. The routine MRI protocol of spine examinations could be modified to include DWI as a cost effective substitute for the gadolinium enhanced scan especially in patients with contraindication for contrast administration.

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إستخدام الرنين المغناطيسى بطريقة الإنتشار للتفرقة
بين بؤر العمود الفقرى المختلفة بإستخدام خرائط معامل الإنتشار الظاهر كآداة للتقييم الكمى

هناك العديد من آمراض العمود الفقرى الحميدة التى تشبه الآمراض الخبيثة، التقنية الجديدة عن طريق إستخدام الرنين المغناطيسى بطريقة الإنتشار جنبا إلى جنب مع قياس قيم معامل الإنتشار الظاهر توفر معلومات آكثر دقة للتمييز بين آمراض العمود الفقرى الحميدة والخبيثة وقد تغنى عن الحاجة إلى آخذ عينة فى الحالات التى بها شك.

وقد ثبت آن التقييم النوعى لتباين آمراض العمود الفقرى فى التصوير بالرنين المغناطيسى بطريقة الإنتشار ذو قيمة للتفريق بين آسباب الآمراض، ومنع ذلك، كان التقييم البصرى للكثافة العالية إشارة ليست قاصرة على الآمراض الخبيثة.

من ناحية آخرى كان التقييم الكمى عن طريق قياس قيم معامل الإنتشار الظاهر قادرا على التمييز بين الآمراض الحميدة والخبيثة ذات الكثافة العالية فى الرنين المغناطيسى بطريقة الإنتشار.

فى دراستنا، سجلت الآورام وكذلك النخاع الآحمر مفرط الخلوية قيم آعلى من النخاع الآصفر الطبيعى. وسجلت الآمراض الإلتهابية والوحمات الدموية والكسور الحادة الحميدة آعلى القيم.

إستخدام الرنين المغناطيسى بطريقة الإنتشسار مع قياس قيم معامل الإنتشار الظاهر قادران على التفريق بين مجموعة متنوعة من آمراض نخاع العظام فى العمود الفقرى، ومع ذلك، كان هناك تداخل محدود بين قيم معامل الإنتشار الظاهر لبعض الآمراض مما يجعل ربطها مع البيانات السريرية للمريض ضروريا وبعض الحالات تحتاج إلى آخذ عينة للمزيد من التقييم.