Diffusion Weighted Magnetic Resonance imaging in Differentiation between Different Vertebral Lesions Using Apparent Diffusion Coefficient (ADC) mapping as a Quantitative Assessment Tool

Ibrahim Said
Department of Radiodiagnosis, Faculty of Medicine for boys, Al-Azhar University, Cairo, Egypt.,
dr.ibrahim_said@yahoo.com

Abdallah El kheshen
Departments of Radiodiagnosis, Al-Azhar University, Faculty of Medicine for boys, Cairo, Egypt,
dr.ibrahim.radiology@gmail.com

Mohamed Belih
Lecturer of radiology, Faculty of medicine for boys, Al-Azhar University, Cairo, Egypt,
drmab_msc@yahoo.com

Follow this and additional works at: https://aimj.researchcommons.org/journal

Part of the Medical Sciences Commons, Obstetrics and Gynecology Commons, and the Surgery Commons

Diffusion Weighted Magnetic Resonance imaging in Differentiation between Different Vertebral Lesions Using Apparent Diffusion Coefficient (ADC) mapping as a Quantitative Assessment Tool

Ibrahim Said Osman Mansour [1]*M.B.B.Ch; Abdallah Mohamed El-Kheshin [2]MD and

Mohammed Abolnaga Mohammed [2]MD.

*Corresponding Author:

Ibrahim Said Osman Mansour

dr.ibrahim_said@yahoo.com

[1]Radiodiagnosis Department, Faculty of Medicine, Al-Azhar University, Cairo , Egypt.

[2]Obstetrics and Gynecology Department, Faculty of Medicine, Al-Azhar University, Cairo , Egypt.

ABSTRACT

Background: Diffusion-weighted imaging (DWI) investigates the microstructure of biological tissue. The variation obtained with this approach, and the estimation of ADC values for the apparent diffusion coefficient, are helpful MRI techniques that may be utilized for non-invasive tissue assessment.

Aim of The Work: To see how valuable both qualitative and quantitative DWI assessments are in distinguishing among spinal tumors, as well as to find a cut-off ADC value among benign and malignant tumors.

Patients and Methods: Studied at the Radio-Diagnosis Department of Sayed Galal hospital, National Cancer Institute. Using 1.5T MRI unit. Sagittal T1WI, T2WI, and axial T2WI & DWI MRI sequences were acquired.

Results: At least one spinal lesion of any kind was detected or suspected in at least 50 people in our study. MRI of the spine using diffusion-weighted imaging has been shown to be effective in determining whether a tumor's origin is benign or malignant. An ADC value analysis, on the other hand, was able to discriminate between benign and malignant increases in DWI signal intensity. The ADC values of cancer-infected bone marrow were higher than those of healthy bone marrow, according to our findings. The highest ADC values were found in inflamed lesions and hemangiomas.

Conclusion: The standard MRI procedure for spine exams should be changed to incorporate DWI as a price alternate to the gadolinium enhanced scan, particularly in patients who are contraindicated to contrast injection.

Keywords: DWI ; Vertebral lesions ; Bone marrow ; ADC ; benign ; Malignant lesions.

INTRODUCTION

An MRI (Magnetic Resonance Imaging) scan is the best way to diagnose, stage, and follow up on Musculoskeletal diseases. When compared to traditional MR scans, Diffusion-weighted imaging (DWI) is a more recent development .[1] DWI provides vital information on cellular water flow in terms of both qualitative and quantitative metrics. It is the tiny self-diffusion of water molecules in tissues that controls DWI signal intensity. Organelles, macromolecules, and cell membranes limit the mobility of internal water molecules, yet these molecules can move more freely because of their increased flexibility. Water mobility at the molecular level will be restricted in locations where cellularity is high (as a result of which there are more intracellular ingredients and cell membranes). [2]

Diffusion-weighted MRI is being effectively employed in the Central Nervous System (CNS), particularly in detection of acute stroke as well as in the differentiation of distinct components of brain cancers. Outside the brain, diffusion measures of cancers have also been recorded.[3]

DWI is a quick MRI procedure that allows for the evaluation of many kinds of vertebral and discal lesions in the spine without contrast medium.[4]

Malignant lesions show primarily hyperintense in diffusion-weighted imaging of the spine. The presence of a hypointense signal in malignant vertebral lesions might be explained by irradiation lesions prior to imaging or sclerotic metastases with extremely low water content.[5]

In cases with degenerative alterations, DWI did not reveal significant signal intensity at the region of endplate anomalies.[6]

Diffusion weighted imaging may also be employed to monitor bone marrow neoplasms after treatment.

When bone marrow illness is effectively treated, tumor cell mortality causes greater water diffusivity, which is shown as higher ADC levels.[7]

Aims of the work: The goal of this research is to see how useful both qualitative and quantitative DWI assessments are in differentiating between various spinal tumors, as well as to find a cut-off ADC values that distinguishes benign from malignant tumors.

PATIENTS AND METHODS

Between February 2018 and October 2021, individuals described with or suspected of having spinal lesion of any cause were studied at the Radio-Diagnosis Department, Faculty of Medicine, Al Azhar University (Sayed Galal hospital), National Cancer Institute, and other radiological institutions. For this ethics committee-approved research, informed consent was acquired.

There were 50 patients in all (27 men and 23 females) ranging in age from 2 to 88 years old (average 49).

Inclusion criteria:

Patients diagnosed with vertebral lesion or vertebral bone marrow abnormality. Patients suspected to have vertebral lesion. Exclusion criteria including patients with pacemaker ,patients with claustrophobia.

The following was done to the patients, Out-patients were given a brief medical history; In-patients, on the other hand, were given more thorough clinical and laboratory data ,Radiological investigations using MRI examination (All patients were subjected to MRI examination). Some patients received IV contrast "gadolinium D.T.P.A" , Also plain X-ray, CT, or bone scan were done for some of the patients.

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

Technique for MR imaging was carried out using a standard 1.5 Tesla unit (Intera and Achieva, Philips) , sense spine coil was used , Spine MRI sequences on a regular basis (Sagittal T1WI, T2WI & STIR , Axial T1WI , T2WI).

After a manual iv gadolinium-DTPA injection of 0.1mmol/kg (in certain cases), contrast enhanced pictures were obtained.

DWI of spine free breathing and inversion recovery were used to conduct DWI utilizing single-shot spin-echo echo-planar sequences. A total of three diffusion-sensitive b-gradients of 0, 50, and 800s/mm2 were employed. The imaging process took six and a half minutes in total.

Image analysis using workstation was used to load all of the images (Philips Medical Systems). An examination of the bone marrow was performed, as well as imaging interpretation .

Qualitative analysis on T1-weighted images, the non-degenerated intervertebral disc signal intensity, sub-cutaneous tissue, and muscular tissue was visually compared to that of the bone marrow signal. We employed previously published diagnostic criteria for spinal bone marrow assessment for MRI interpretation.

Quantitative analysis measurements in Areas of Interest allowed the radiologist to estimate bone marrow signal strengths (ROI). Hyperintense lesions (with a "b 800" b-value), which correlate to aberrant signal intensity fluctuations on both T1 and T2 MRI, were manually delineated inside the ROI. If a patient had a diffuse vertebral marrow lesion, the ROI was drawn as big as feasible in order to prevent vertebral end plate degeneration and block access to the basivertebral vein plexus. Furthermore, by inserting ROI at the middle of the vertebral bodies, the ADC value of normal/normal seeming vertebral bodies was assessed. The diameter of the zones of interest ranged from 5 to 15mm. At least three ROIs were administered to each subject. The ADC values were automatically created employing software produced by the MR scanner provider, and the ADC quantitative feature was displayed in the following ranges: 10–3mm2/s (Philips Medical Systems). The average ADC value was computed and reported for each patient's 3 areas of interest. The "standard method" for classifying the spinal marrow tumors was the ultimate diagnosis, which was determined based on biopsy findings or clinical and radiologic follow-up outcomes.

RESULTS

A sum of 50 patients (27 men and 23 females) with ages ranging from 2 to 88 (average 49) were assessed radiologically for spinal lesion of any cause.

Classification of the vertebral bone marrow abnormalities:

The research comprised 26 patients with benign and 24 patients with malignant spinal marrow infiltrative tumors (Table 1). Clinical, radiographic, and histological evidence are used to make this diagnosis. Nine individuals had inflammatory/infectious spondylitis or spondylodiscitis, 11 had benign neoplastic marrow lesions, three had diffuse yellow to red marrow reconversion, and three had degenerative marrow alterations among the 26 patients with benign marrow lesions.

Metastatic lesions (n=17), lymphomatous infiltration (n=1), and multiple myeloma (n=1) were among the 24 individuals with malignant spinal marrow lesions that are infiltrative or multifocal.

No. of patients	Group
9	Inflammatory
11	Benign neoplastic lesion
24	Malignant neoplastic lesion
3	Red marrow
3	Degenerative

Table 1: Classification of the vertebral bone marrow abnormalities.

Inflammatory lesions:

On DWIs, all lesions in the inflammatory group revealed increased signal intensity. The median ADC value of pyogenic spondylodiscitis was high (mean; 1.454 X 10–3mm2/s, SD ±0.16 X 10–3mm2/s) while TB spondylodiscitis were of lower ADC values (mean; 1.191 X 10–3mm2/s, SD ±0.29 X10–3 mm2/s) (Table 2).

Diagnosis	DWI signal	ADC value (X 10$_{-3}$mm$_2$/s)	
		Range	Mean ± SD
Pyogenic spondylodiscitis TB spondylodiscitis	High High	1.369-1.690 0.902-1.564	1.454±0.16 1.191±0.29

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

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 lower signal intensity while the osteoblastoma revealed higher signal intensity. The median ADC value of the hemangioma was high (median; 1.406 X 1 0–3mm2/s, SD ±0.13 X 10–3mm2/s) while osteoblastoma was of lower ADC value (0.818 X 10–3mm2/s) (Table 3).

Diagnosis	DWI signal	ADC value (X 10$_{-3}$mm$_2$/s)	
		Range	Mean ± SD
Hemangioma	Low	1.254-1.512	1.406±0.13
Osteoblastoma	High	0.818	

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

Malignant Neoplastic lesions:

A total of nineteen cases with malignant verte-bral 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 median ADC value of the non-treated malignant tumors was (median; 0.982 X 10–3mm2/s, SD ±0.17 X 10–3 mm2/s) while the two lesions under therapy were of higher ADC values (1.612 & 1.483 X 10–3 mm2/s) (Table 4).

Diagnosis	DWI signal	ADC value (X 10–3mm2/s)	
		Range	Mean ± SD
• *Metastasis:* Pretherapy. Post therapy	High	0.624-1.237	0.982±0.17
	High	1.612	
• Multiple myeloma.	Low	0.975	
• *Lymphoma:* Post therapy.	High	1.483	

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

The ADC obtained values from the ADC maps generated automatically. (Table 7) vary substantially (p-value <0.001, highly substantial) between malignant (median, 0.982 X 10–3mm2/s; SD ±0.17 X 10–3mm2/s) and the following benign marrow entities; inflammatory pyogenic marrow tumors (median, 1.454±0.322 X 10–3mm2/s; SD ±0.16 X 10–3mm2/s) and the degenerative marrow changes (median, 0.569 X 10–3mm2/s; SD ±0.06 X 10–3 mm2/s). ADC values of malignant lesions also differed substantially (p-value 0.002, substantial) from the hemangiomas (mean, 1.406±0.13 X 10–3 mm2/s; SD ±0.16 X 10–3mm2/s).

The ADC values of malignant tumors and TB spondylodiscitis were found to be similar(median, 1.191 X 10–3mm2/s; SD ±0.29 X 10–3 mm2/s), yet with a statistically substantially variance (p-value 0.034, significant) in their ADC values. An overlap between the ADC values of malignant tumors and the red marrow (median, 0.613 X 10–3 mm2/s; SD ±0.08 X 10–3mm2/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 X 10–3mm2/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 X 10–3mm2/s and "lymphoma" 1.483 X 10–3mm2/s were greater than those of pretherapy malignant lesions (median, 0.982 X 10–3mm2/s; SD ±0.17 X 10–3mm2/s).

Receiver Operating Characteristics (ROC) curve was utilized to define the best cut off value of ADC (10–3mm2/sec) among benign and malignant lesions which was < 1.237, With a sensitivity of 100 % and a specificity of 61.9 %, the predictive accuracy of 66.7 is 66.7 percent, the negative prediction accuracy is 100 percent, and the diagnostic accuracy is 72 percent.
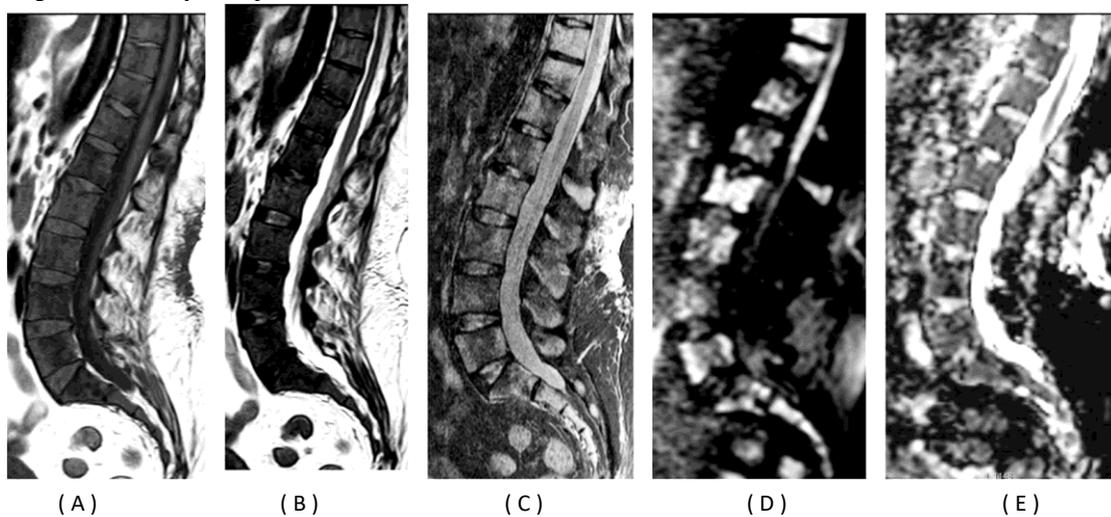

(A)   (B)   (C)   (D)   (E)

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 p–a3tchy 2areas of bright signal intensitieson STIR images and patchy areas of restricted diffusion. ADC value: 1.061 X 10 mm /s.

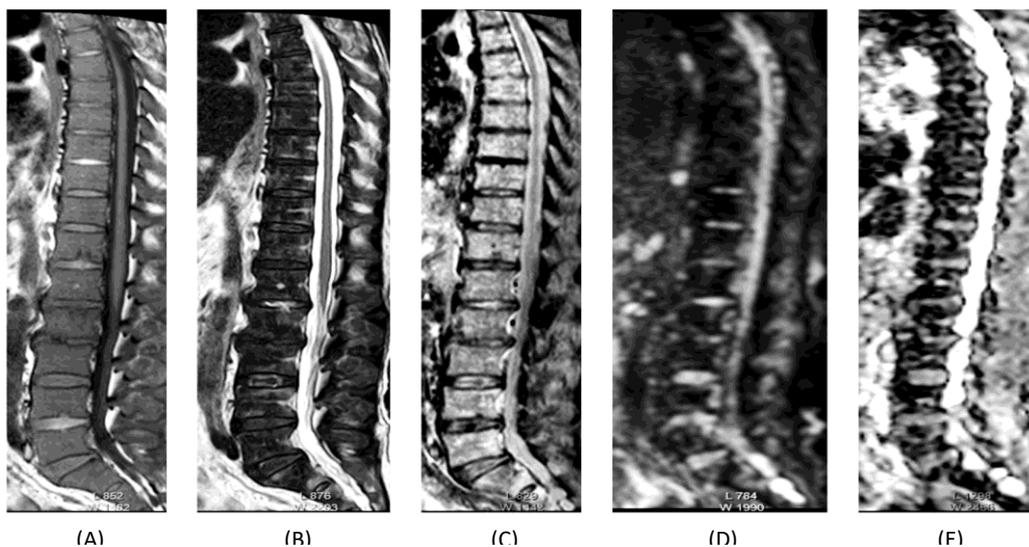(A)   (B)   (C)   (D)   (E)

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 decreased signal on both T1

& T2 WIs and rather diffuse increased signal intensity on STIR images with no areas of restricted diffusion noted. ADC value: 0.975 X 10 –3 mm2/s
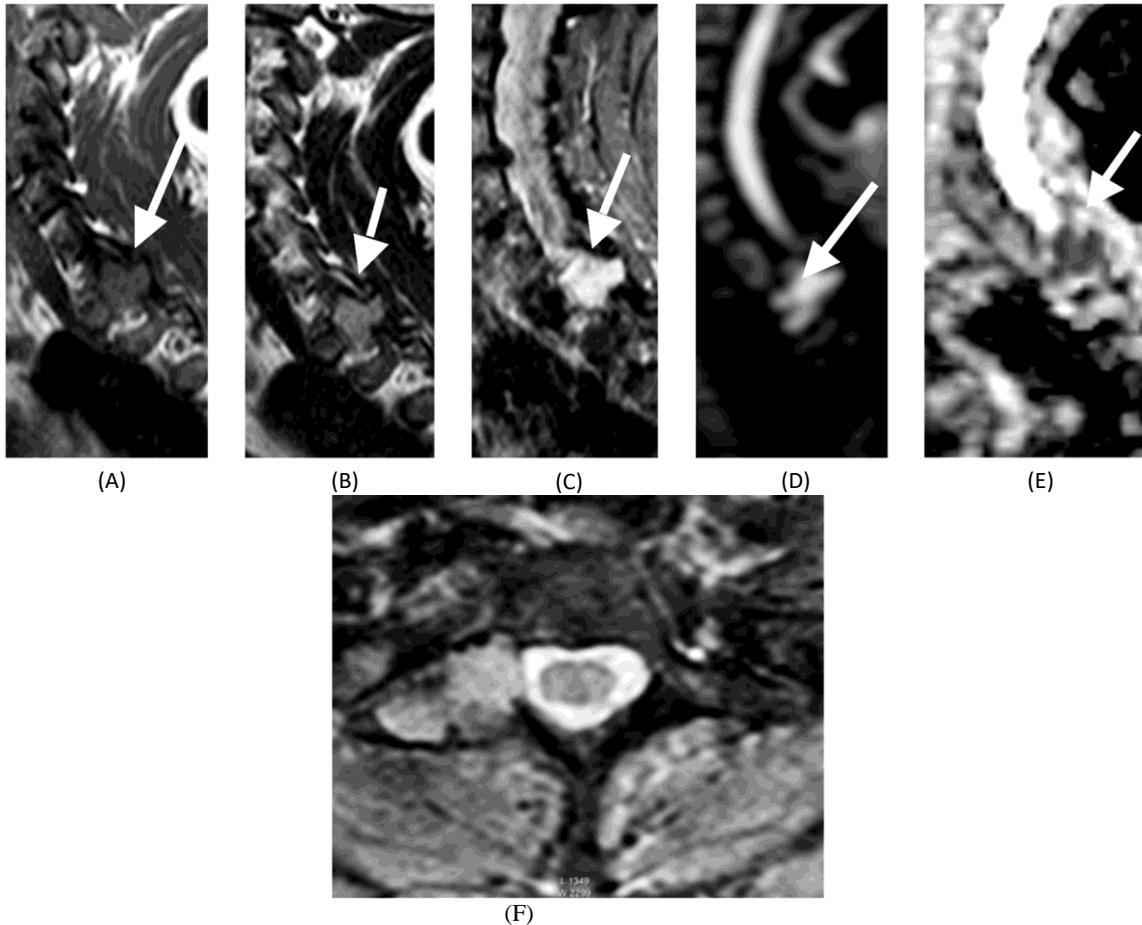

(A) (B) (C) (D) (E)

(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 corr–e3spon2ding area of restricted diffusion. ADC value: 0.818 X 10 mm /s
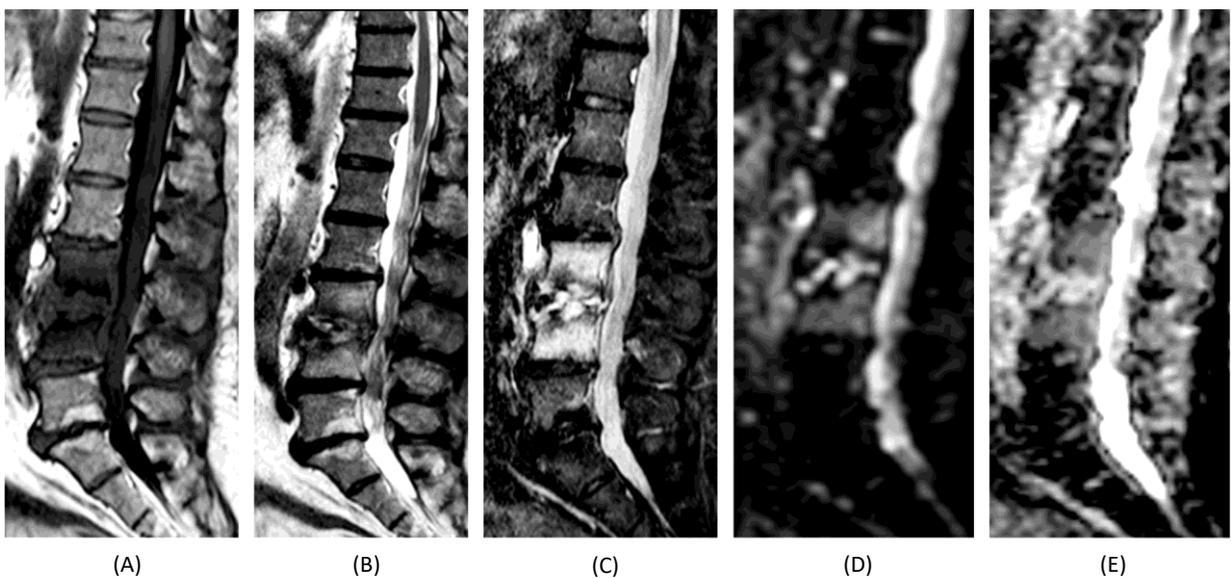

(A) (B) (C) (D) (E)

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. The sagittal T2-weighted picture and sagittal

STIR demonstrate a strong association.L3 and L4 vertebrae signal intensity, as well as the intervening L3/4 disc, with L3 and L4 vertebrae and intervening disc diffusion restriction. ADC value: 1.369 X 10 –3 mm2/s.

DISCUSSION

In addition to the macroscopic data provided by normal MR sequencing, diffusion weighted MR sequences include microscopic data. It's a non-invasive imaging technique that leverages the randomized, translational motion of water protons in a biological tissue to reveal tissue specific diffusion capabilities and may be utilized to characterize tissues.

Because inflammation and overactive hematopoietic marrow may induce comparable diffusion constraints, we determined that visual evaluation of enhanced signal strength on a higher b-value (800) was not particular for malignancies in this investigation. [6]

The quantitative evaluation, on the other hand, was capable to discriminate benign from increased signal strength on DWI by calculating the ADC value. This was in line with the findings of who stressed the need of matching higher b-value DW images with comparable ADC values. [7]

This was consistent with our findings, which showed that infiltrating neoplastic marrow and hypercellular red marrow had greater ADC values, whereas inflammatory lesions and hemangiomas had the greatest.

In contrast, according to Padhani[7]and Zidan[6], there was low signal strength and ADC value variety among malignancy and red marrow, but the ADC value variance among the both entities was statistically substantial with a p of 0.002.

Pyogenic vertebral lesions had a median ADC value of 1.45±0.16 X 10–3 mm2/sec, which was considerably greater than malignant vertebral tumor (0.98±0.17 X 10–3 mm2/sec) (p<0.001).

The median ADC value of pyogenic vertebral tumors was 1.71±0.12 X 10–3mm2/sec, which was considerably greater than that of carcinomas spinal tumors (0.75±0.23 X 10–3mm2/sec) (p=0.007), with no overlap Abo Dewan[8]. Infected lesions exhibited a median ADC of 1.54±0.115 X 10–3mm2/sec, which was substantially increased than malignant tumors (p<0.0001), according to Taskin[9].Only two of the 23 spinal infected tumors had ADC values that matched those of malignant tumors, according to the researchers.

In contrast to our findings, Fawzy [10] claimed that the ADC values of infected malignant lesions were identical, making it impossible to distinguish between the two.

The median ADC value of tuberculous metastases was 1.19±10.29 X 0–3mm2/sec in our research, with some overlap among tuberculous and malignant lesions but a statistically substantial variance with malignant lesions (p=0.034).

Abo Dewan[8] found that the average ADC value of tuberculous metastases was 0.910.08 X 10–3mm2/sec, with non-significant deviation from that

of malignant tumors (p=0.143) and overlap between tuberculous and malignant tumor. It was determined that the ADC values of TB metastases were generally 1.4x0–3 mm2/sec by Palle [11] for the classification of malignant lesions, which had a sensitivity, specificity, and high predictive value of 64.8%, 75%, and 74.5% respectively. They noted, however, that since the ADC values of meta-static vertebral lesions overlap with the ADC values of this ADC value, Clinical history and routine MR results should be considered with the ADC data. Despite the fact that the number of TB metastases in our investigation was far less than the number of lesions found in the other study, these findings were very comparable to our own. [11]

DWIs can distinguish between atypical hemangioma and metastatic spine tumours, according to our findings. In this investigation, we discovered that atypical and normal hemangiomas had non-limited diffusion as low signal on DWI, but metastases had restricted diffusion as higher signal on DWI and low signal on ADC maps. In comparison to normal and atypical hemangioma, metastatic bone lesions had much lower ADC values. These distinctions were immediately noticeable. The median ADC value of hemangiomas was determined to be 1.406 X 1 0–3mm2/sec in our investigation. The ADC of metastatic bone lesions was reported to be 0.982 X 10–3mm2/sec on average.

This was in accordance with Matrawy [12], who said that limited diffusion was evident in metastasis but not in hemangiomas, with the median ADC value of hemangiomas being 1.54 X 10–3mm2/sec and the median ADC value of metastatic bone lesions being 0.83 X 10–3mm2/sec, respectively. ADC values for atypical hemangiomas have also been reported to range between 1.94 and 2.82 X 10–3 mm2/sec . [9] The ADC values of benign lesions were among 0.43 and 1.44 X 10–3mm2/sec, with a median ADC value of 0.94±0.34 X 10–3mm2/sec, while the ADC values of metastatic lesions are within 0.43 and 1.44 X 10–3mm2/sec, with a median ADC value of 0.94±0.34 X 10–3 mm2/sec.

Eguchi [5] found that all patients with spinal infections had hyperintensity of vertebral bone marrow on DWIs, but none of the patients with degenerative abnormalities. Infectious bone marrow has considerably higher ADC values than normal and degenerative bone marrow.

CONCLUSION

Diffusion weighted MRI is a useful method for identifying various vertebral bone marrow disorders. The standard MRI procedure for spine exams should be changed to incorporate DWI as a price alternative to the gadolinium enhanced scan, particularly in patients who are contraindicated to contrast injection.

Conflict of interest : none

REFERENCES

1-KHOO M.M , TYLER P.A , SAIFUDDIN A. Diffusion-Weighted Imaging (DWI) in musculoskeletal MRI: A critical review. *Skeletal Radiology* . 2011 ; 40: 665-81.

2-KHEDR S.A., HASSAAN M.A., ABDELRAZEK N.M. Diagnostic impact of echo planar diffusion-weighted magnetic resonance imaging (DWI) in musculoskeletal neoplastic masses using Apparent Diffusion Coefficient (ADC) mapping as a quantitative assessment tool. *Journal of Radiology and Nuclear Medicine* .2012 ; 43: 219-26 .

3-DALLAUDIÈRE B., DAUTRY R., and SERFATY J. Comparison of apparent diffusion coefficient in spondylarthritis axial active inflammatory lesions and type 1 Modic changes. *European Journal of Radiology* . 2014 ; 83: 366-70 .

4-PUI M.H., MITHA A., RAE W.I. and CORR P.Diffusion-weighted magnetic resonance imaging of spinal infection and malignancy. *J. Neuroimaging*.2015; 15: 164-70.

5-EGUCHI Y., OHTORI S., YAMASHITA M., TOYONE T. and TAKAHASHI K. Diffusion magnetic resonance imaging to differentiate degenerative from infectious endplate abnormalities in the lumbar spine. *Spine*.2011 ; 36: 198-202 .

6-ZIDAN D.Z. and ELGHAZALY H.A.Can unenhanced multiparametric MRI substitute gadolinium-enhanced MRI in the characterization of vertebral marrow infiltrative lesions. *The Egyptian Journal of Radiology and Nuclear Medicine*.2014

7-PADHANI A., KOH D.M. and COLLINS D. Whole-body diffusion-weighted MR imaging in cancer: Current status and research directions. *Radiology*.2011; 261: 3.

8-ABO DEWAN K.A.W., SALAMA A.A., EL HABASHY H.M.S. and KHALIL A.E.S. Evaluation of benign and malignant vertebral lesions with diffusion weighted magnetic resonance imaging and apparent diffusion coefficient measurements. Egypt. *J. Radiol. Nucl. Med*.2013; 46: 423-33.

9-TAŞKIN G., INCESU K. and ASLAN K.The value of apparent diffusion coefficient measurements in the differential diagnosis of vertebral bone marrow lesions. *Turk. J. Med*. Sci.2013 ; 43: 379-87 .

10-FAWZY F., TANTAWY H.I., RAGHEB A. and ABO HASHEM S.Diagnostic value of apparent diffusion coefficient to differentiate benign from malignant vertebral bone marrow lesions. *The Egyptian Journal of Radiology and Nuclear Medicine*.2013 ; 44: 265-71 .

11-PALLE L., REDDY M.B. and REDDY K.J. Role of magnetic resonance diffusion imaging and apparent diffusion coefficient values in the evaluation of spinal tuberculosis in Indian patients. *Indian J. Radiol. Imaging*.2010; 20: 279-83 .

12-MATRAWY K.A., EL-NEKEIDY A. and EL-SHERIDY H.G. Atypical hemangioma and malignant lesions of spine: Can diffusion weighted Magnetic Resonance Imaging help to differentiate. *The Egyptian Journal of Radiology and Nuclear Medicine*.2013 ; 44: 259-63.