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Research Paper

Role of Diffusion Weighted Imaging Sequences to Differentiate between Modic Change Type 1 and Spondylodiscitits

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ABSTRACT:

BACKGROUND:

Diffusion Weighted Imaging (DWI) has gained increasing use in diagnosing pathology in the spine, and is becoming valuable in the assessment of a variety of diseases including tumor and infection. Modic type 1degenerative changes on conventional MR imaging can mimicor suggest infection, leading to additional costly and sometimes invasiveinvestigations.

OBJECTIVE:

To study the role of DWI in uncertain (doubtful) cases with overlapping conventional MRI signal features between Modic1 degenerativechange and infectious spondylodiscitis and describe different patterns of diffusionrestriction.

PATIENTS AND METHODS:

Cross sectional study was done at radiology department of Al-Imamain Al Kadhimain Medical city.Studywas done from October 2021 and November 2022 with a convenient sample of 53patients. The patients were sent for spinalMRI and had clinically suspected to have Modic type 1change or discitis.Conventional MRI with sagittal DWI was done for all patients. Patients were classified as either had Modictype 1 degenerative changes or discitis.

RESULTS:

Thirty-six of patients (68%) were Modic type 1 degenerative changes and 17 (32%) patients had spondylodiscitis.The definite Claw sign was found among 19(52.8%) of the patients, probableClaw sign found among 10(27.8%), questionable Claw sign foundamong 6(16.7%) of the patients, while none of those (0%) of those with spondylodiscitis had these signs. Diffused Abnormal DWI (negative claw sign) signal found among 1(2.8%)of those with Modic 1 in comparison to 3(16.7%) of those with discitis.

CONCLUSION:

DWI is useful for differentiating Modic type 1 degenerative changes andinfectious spondylodiscitis. The claw sign is useful and accurate sign for distinguishing Modic type 1 endplatedegenerative changes from spondylodiscitis.

KEYWORDS: Diffusion Weighted Imaging, Modic Change, Spondylodiscitits.

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INTRODUCTION:

The definition of spondylodiscitis in the strict sense applies to infectious diseases; however, there are several non-infectious conditions that can mimic the presence of an infectious vertebral disease. The distinction between inflammatory/ degenerative versus infectious pathology has a huge prognostic impact [(1)].

Magnetic resonance imaging (MRI) is considered the imaging modality of choice for the detection and evaluation of spondylodiscitis, with a sensitivity of 96% and specificity of 92% in the diagnosis of infectious processes [(2)].

Modic changes (MCs) are magnetic resonance imaging (MRI) findings of vertebral bone marrow changes extending from the endplate. They are divided into type 1 (oedema type), 2 (fatty type) and 3 (sclerotic type) based upon T1- and T2-weighted images [(3)]. They have been identified and described as the causative factor for low back pain [(4)].

Type 1 MCs were related to back pain in some studies [12a,13a], but the clinical significance of MCs is uncertain [5]. Modic changes are more prevalent in patients with degenerative disc disease but are uncommon in asymptomatic individuals without degenerative disc disease [6]. Modic type 1 changes are seen much more frequently in patients with low back pain (46%) compared to asymptomatic general population (6%) [7].

There are limited data on ADC measurements in MCs, but DWI and ADC values have been used to help distinguish type 1 MCs from infectious spondylitis and inflammatory spondyloarthritis [8-12].

AIMS OF THE STUDY:

This study aimed to study the role of DWI in the uncertain (doubtful) cases that show overlapping conventional MRI signal features between Modic I degenerative change and infectious spondylodiscitis and describe different patterns of diffusion restriction.

PATIENTS AND METHODS:

Study design and setting: a prospective study was done at MRI Department of Al-Imamain Al-Kadhimain Medical city.

Study population: all patients sent for spinal MRI who clinically suspected to have ModictypeI changes or spondylodiscitis.

Study period: the study was carried out from October 2021 to November 2022.

Sample size: a sample of 53 patients.

Inclusion criteria:were the presence of low back pain and/or feveraccompanied with bone marrow changes at one or more end plates on conventional MRI examination detectable as hypointensity on T1W images and hyperintensity on T2W/STIR images with or without intervening intervertebral disc involvement.

Exclusion criteria: were a history of previous spinal surgery, intervertebral disc extrusion or sequestration, vertebral compression fractures, a known case of infectious discitis on treatment, a known case of primary malignancy and spinal metastasis, general contraindication to MRI examination.

Ethical consideration: the study was approved by the scientific committee of the Iraqi Board ofdiagnostic radiology. Verbal informed consent was obtained from all patientsincluded in the study.

MRI and DWI Protocol: all patients were examined by 1.5-T MRI scanner (Magnetom Avanto, Siemens Healthineers, Germany). Patients were scanned in the supine position using a SENSE XL TORSOcoil, and conventional MRI sequences were done including T1 WI, T2/STIR WIwith/or without T1 post IVgadolinium contrast images.Additional sagittal DWI was performed using diffusion-weighted singleshot imaging with background body signal suppression (DWIBS). The following imaging parameters were set:Sagittal T1-weighted (repetition time (TR)/echo time (TE) 400/14).SagittalT2-weighted/STIR spine echo (TR/TE, 4000/102)/ (TR/TE, 3500/60). Sequenceswere obtained using a 256 256 matrix, 260 mm FOV, and 3/1mm slice thickness/gap.Sagittal DWI (1000s/mm2 b-value, MPG direction phase, frequencyand slice, 3500/74 /170ms for TR/TE/TI respectively, sagittal slice orientation,4/–1 mm slice thickness/gap, 400 mm field of view (FOV), 160 125 matrix,2.5 3.194.0 mm3 actual voxel size, 1.6 1.6 4.0 mm^3 calculated voxel size, 6 excitations, 3 acquisitions, and 9min 18sec scan time.

Image Analysis and interpretation: image interpretation was done by a specialist radiologist;T1 hypointensity was considered if signal was lower than the paraspinal muscle signal intensity. T2/STIR hyperintensity was considered when similar or higher signal is seen within the vertebral end plate (and/or the IVD) relative to the nucleuspulposus of the well hydrated disc orhigher signal than the other end plate suppressed signal.

Abnormal Diffusion of the end plate was defined as high signal intensityof the involved vertebral end plates on single shot DWI.Patterns of abnormal DWI signal were as follow:Claw sign: is defined as a well marginated linear, typically paired regions ofhigh signal situated within adjoined vertebral bodies at the boundaries betweenthe normal bone marrow and vascularized bone marrow that lies close to the affected disc, presumed to represent a form of physiological reactive response or induration. Probable claw sign: is a probable linear well marginated paired region of highsignal involving half of the vertebral bodies.Questionable claw sign: is a faint linear marginated paired region of high signalsituated within adjoined vertebral bodies. Negative claw sign: Diffuse signal on DWI involving the whole vertebralbodies. The patients were classified according to DWI signal and pattern andwere compared to the final diagnosis of either Modic or spondylodiscitis which were supported by the following procedures: laboratory findings such asblood culture, elevated erythrocyte sedimentation rate, and leukocytosis andfollow up of the patients

for 4-6 weeks period.No restriction: the signal of involved vertebra was similar to normal vertebrae.

Statistical analysis:

Data obtained was documented, processed and analyzed using StatisticalPackage for Social Sciences (SPSS) version 25, and Microsoft excel (2010).Descriptive analysis was used to summarize data. Categorical data weresummarized in percentages. Continuous variables were summarized by use ofmean with their respective measures of dispersion. P value of <0.05 was takenas cut off level of statistical significance.Sensitivity: It is the proportion of people who tested positive for the diseasecompared to the number of all people with disease irrespective of their test result. Specificity: It is the proportion of healthy people who tested negative comparedto total number of people not having disease irrespective of their test result. In order to determine the sensitivity we use the formula Sensitivity = true positives/ (true positives+ false negative).To calculate the specificity we use the equation Specificity= true negative/(false positives+ true negative).

Positive predictive value (PPV) is the ability of the test to correctly labelpeople who test positive. PPV = (true positives)/ (true positives+ false positives). Negative predictive value (NPV) is the ability to correctly label people who test negative. NPV= (true negative) / true negative+ false negative).

RESULTS:

This study included 53 patients with low back pain and/or fever. Theywere 14 males (26%) and 39 females (74%). The final diagnosis showed 36 (68%) patients had Modic type I degenerative changes and 17(32%) patients had spondylodiscitis. The sex distribution of the patients according to the disease show that 29 (80.6%) of those with Modic type I were female in comparison to 7(19.4%)were male. Those with discitis also show that 10(58.8%) were female and7(41.2%) were male,this difference was statistically not significant.

The back pain reported among 34(94.4%) of the Modic type 1 patients, back pain and/or fever found among 14(82%) of the spondylodiscitis patients, this relation was statistically significant (P value=0.0000013), as shown in(table 1)

Table 1: Distribution of patient according to clinical presentationand diagnosis.

Clinical	Modic type 1		Discitis		P value
	No.	%	No.	%	
Back pain	34	94.40%	3	17.60%	0.0000013
Back pain and/ or fever	2	5.60%	14	82.40%	
Total	36	100%	17	100%	

Hypo intensity of IVD (T2/STIR) found among 34(94.4%) patients with Modic type 1 and 2(11.8%) patients with spondylodiscitis, while hyperintensity of IVD found in 15(88.2%) patients with spondylodiscitis and 2(5.6%)patients with Modic type 1 changes, this relation was statistically significant (Pvalue = 0.00000017).

Abnormal DWI signal intensity found among 36(100%) patients with Modic 1 changes and 3(16.7%) patients with discitis, while non-restricted signal found among 0(0%) patients with Modic 1 and 14 (82.3%) patients with spondylodiscitis, this relation was statistically significant (pvalueis 0.001).

The Abnormal signal DWI intensity were sub-divided into 4 patterns:the definite Claw sign (1) found among 19(52.8%) patients with Modic 1changes, probable Claw sign (2) found among 10 (27.8%) patients with Modic 1changes, questionable Claw sign (3) found among 6(16.7%) patients with Modic 1 changes. No patients (0%) with spondylodiscitis show the above3 signs in DWI. diffused abnormal DWI (negative claw sign) (4) found among 1(2.8%) patient with Modic 1 and in 3(16.7%) patients with spondylodiscitis, this relation was statistically significant (P value= 0.001) as shown in (table2).

Table 2: Patterns of abnormal DWI signal intensity in patients with Modic Type 1 and Infectious Spondylodiscitis.

Abnormal DWI	Modic type 1		Discitis	
	No.	%	No.	%
Definite Claw sign (1)	19	52.8%	0	0%
Probable Claw sign (2)	10	27.8%	0	0%
Questionable Claw sign (3)	6	16.7	0	0%
Diffused Abnormal DWI(negative claw sign)(4)	1	2.80%	3	16.7
Not restricted	0	0%	14	82.3%
Total	36	100%	17	100%

X2 =49.5, df=4, P value =0.001 significant

The Post contrast enhancement of intervertebral disc was positive among11(30.6%) patients with Modic 1 changes and 16(94.1%) patients withspondylodiscitis, while it was negative among 25(69.4%) patients with modic changes and 1(5.9%) patient with spondylodiscitis, this relation was statistically significant (P value =0.00016).

The Definite Claw sign (1) show sensitivity of 52.8% with false negativerate of 47.2%, and positive predictive value of 100% (100% of those have thesign will be truly diagnosed as Modic type 1) and specificity in diagnosis ofmodic1 cases was 100%, false positive rate was 0% (0% of those diagnosed asmodic1 changes they are in fact not Modic 1 changes. The negative predictivevalue was 50% (50% of those who didn‘t have the sign will be truly diagnosed as negative for Modic 1 changes). The Probable Claw sign (2) sensitivity andspecificity in diagnosis of Modic 1 case was 27.8%, 100% respectively, thefalse positive and false negative rates were 0%, 72.2% respectively. TheQuestionable Claw sign (3) sign sensitivity and specificity in diagnosis ofModic 1 cases was 16.7%, 100% respectively, the false positive and falsenegative rates were 0%, 83.3% respectively. The Abnormal Diffused DWI(negative claw sign) (4) sign sensitivity and specificity in diagnosis of Modic 1cases was 2.8%, 82.4% respectively, the false positive and false negative rateswere 17.6%, 97.2% respectively. Positive Claw sign (Definite+ Probable+questionable) show sensitivity to 97% in diagnosing Modic 1 (table3).

Table 3: Sensitivity, specificity, accuracy, PPV and NPV of Claw sign (various pattern of DWI signal) for the diagnosis of Modic type 1.

	Sensitivity	Specificity	False +ve	False -ve	Accuracy	PPV	NPV
Definite Claw sign (1)	52.8%	100%	0%	47.2%	67.9%	100%	50%
Probable Claw sign)	27.8%	100%	0%	72.2%	50.9%	100%	39.5%
Questionable Claw sign (3)	16.7%	100%	0%	83.3%	43.4%	100%	36.2%
Diffused Abnormal DWI (4)	2.8%	82.4%	17.6%	97.2%	28.3%	25%	28.6%
Positive claw sign (1+ 2+3)	97.2%	100%	0%	2.8%	98.1%	100%	94.4%
Not restricted	2.8%	17.6%	82.4%	97.2	7.5%	6.7%	7.9%

The sensitivity of the no restricted DWI in diagnosis of spondylodiscitis was 82% (82% of those who have discitis will be diagnosed as discitis using theDWI), with false negative rate of 18% (18% of those with discitis will falsely be diagnosed as negative for discitis), and PPV of 100%. Specificity in diagnosis of discitis cases was, 100% (100% of those who didn‘t have discitis will be diagnosed as not having discitis), false positive rate was 0% (0% of those truly have discitis will falsely be diagnosed as discitis.

Regarding post contrast enhancement the sensitivity was 94%, and specificity was 69% in the diagnosis of spondylodiscitis, false positive and false negative rate were 31%, 6% respectively, PPV was 59%, NPV was 96.2% as shown in (table 4).

Table 4: Sensitivityspecificity, accuracy, PPV and NPVof the post contrast enhancement and normal DWI, for the diagnosis of spondylodiscitis.

	Sensitivity	Specificity	False +ve	False -ve	Accuracy	PPV	NPV
DWI non-restricted signal	82%	100%	0%	18%	94% %	100%	92.3%
Post contrast	94%	96%	31%	6%	77%	59%	96.2%

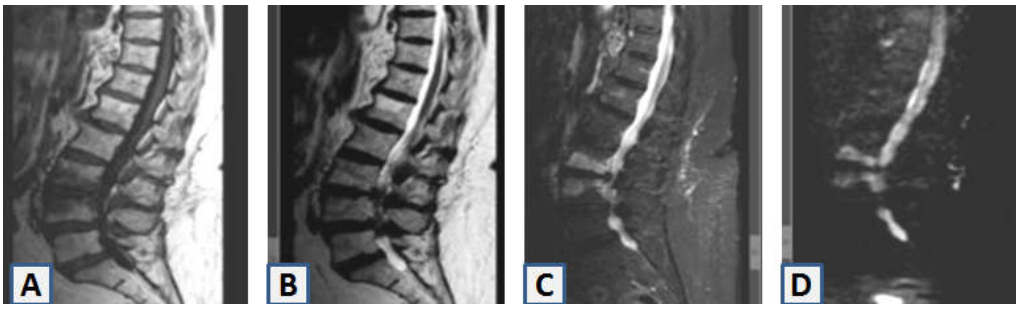

Figure 1: 70 years old female presented with back pain. A: Sagittal T1 show L3-4 endplate hypo signal intensity.B: Sagittal T2 show L3-4 endplate hyper signal intensity.C: Sagittal STIR show L3-4 endplate hypersignalintensity.D. Sagittal DWI show L3-4 definite claw sign, the final diagnosis was Modic 1 degenerative changes.

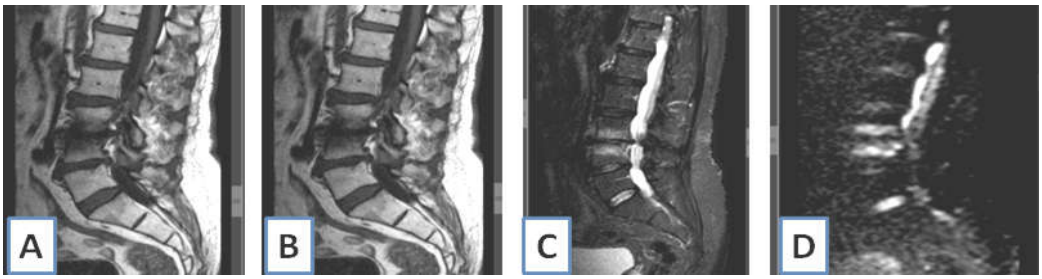

Figure 2: 56 years old male presents with back pain. A: Sagittal T1show L3-4 endplate hypo signal intensity. B: Sagittal T2 show L3-4 endplate hyper signal intensity. C: Sagittal STIR shows L3-4 endplate hyper signal intensity. D: Sagittal DWI show L3-4 probable claw sign, final diagnosis was Modic 1 degenerative changes.

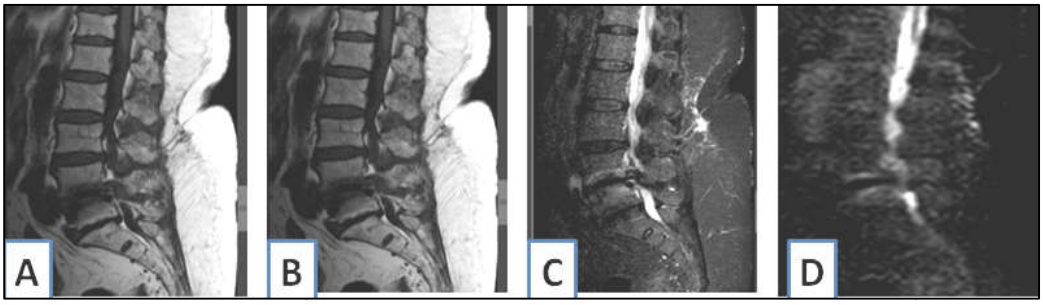

Figure 3: 46 years old male presents with back pain. A: Sagittal T1 show L4-5 endplate hypo signal intensity. B: Sagittal T2 show L4-5 endplate hyper signal intensity. C: Sagittal STIR showsL4-5 endplate hyper signal intensity. D: Sagittal DWI show L4-5 questionable claw sign, the final diagnosis was Modic 1 degenerative changes.

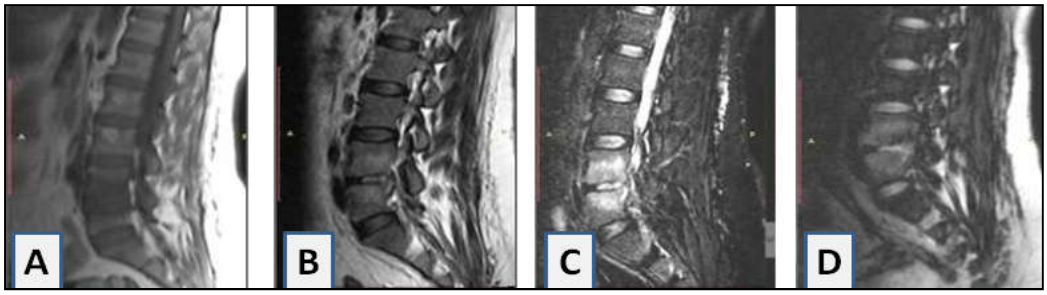

Figure 4: 41 years old female presents with fever and back pain. A: Sagittal T1 show L4-5 endplate hypo signal intensity. B: Sagittal T2 show L4-5 endplate hyper signal intensity. C: Sagittal STIR showsL4-5 endplate hyper signal intensity. D: Sagittal DWI show L4-5 endplate diffuseabnormal signal (negative claw sign), final diagnosis was Modic 1 changes.

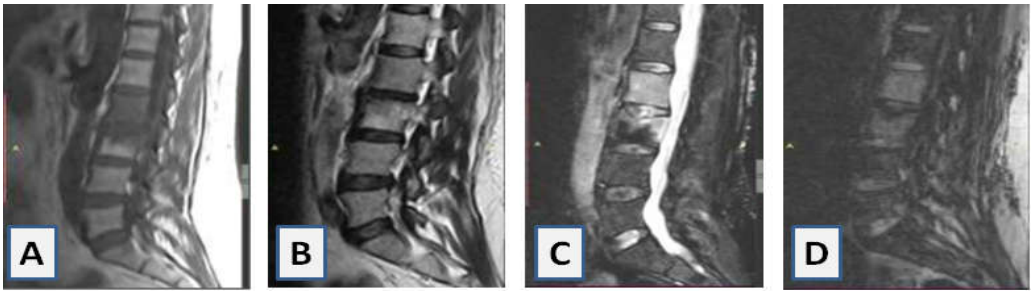

Figure 5: 46 years old female presents with back pain. A: Sagittal T1 show L2-3 endplate hypo signal intensity. B: Sagittal T2 show L2-3 endplate hyper signal intensity. C: Sagittal STIR shows L2-3 endplate hyper signal intensity. D: Sagittal DWI show L2-3 endplate diffuseabnormal signal (negative claw sign), the final diagnosis was spondylodiscitis.

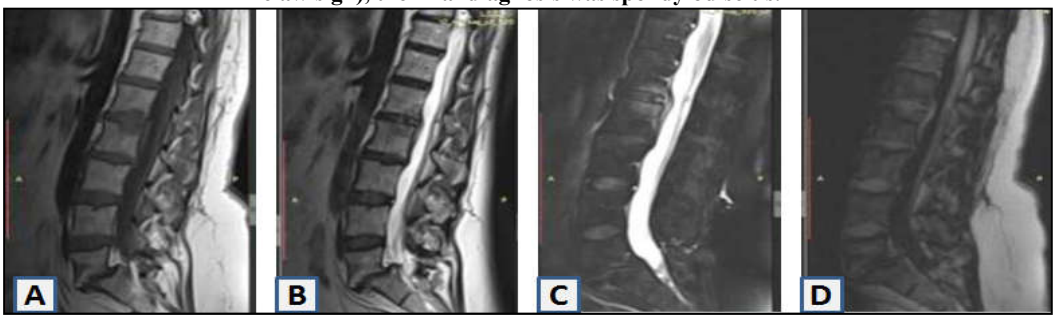

Figure 6: A 48 years old female patient presents with fever and back pain. A: Sagittal T1 demonstrate L1-2 endplate hypo signal intensity. B: Sagittal T2 demonstrate L1-2endplate hyper signal intensity. C: Sagittal STIR demonstrates L1-2 endplate hyper signalintensity. D: Sagittal DWI demonstrates L1-2 endplate normal DWI, the final diagnosiswas spondylodiscitis.

DISCUSSION:

Because of increasing spinal surgeries and expanding use of LSS MRIs, degenerative end plates changes and spinal infections are now encountered more frequently and sometimes cause a diagnosis challenge [13]. As a result of nonspecific clinical and laboratory findings, the diagnosis of spinal infection become sometimes difficult especially when overlapping clinical and MRI signal characteristics of spinal infections and Modic I changes do exist [14].

The current study included 36 (68%) patients with final diagnosis of Modic type I degenerative changes and 17 (32%) patients with spondylodiscitis, these results were comparable to those presorted in the previous studies [15-17].

In this study the back pain was reported among 34 (94.4%) of the Modic type 1 patients and back pain and/or fever found among 14 (82%) of the spondylodiscitis patients. These findings were similar with Herlin C et al study[18].

In the current study the hypointensity of IVD (T2/STIR) was found among 34 (94.4%) of Modic 1 changes patients, while in 15 patients (88.2%) of those with spondylodiscitis had disc hyperintensity in a statistically significant relation. Similar results were observed by Patel KB, et al study [19].

In this study, the abnormal DWI signal intensity was found in 39 patients of 53 (74%) while the remaining 14 (26%) patients showed no restricted signal on DWI, among the 39 patients (whom had abnormal signal on DWI) 36 (92%)were show Modic I and only 3 (8%) patients were spondylodiscitis, these results were comparable to the results of Patel KB et al [19]that had 73% of the patients were Modic and 26% were spondylodiscitis. Madhok et al [20]studied the role of DWI in cases of spondylodiscitis and showed that in cases of TB spondylodiscitis no diffusion restriction on DWI had been observed, this was in agreement with the results of this study regarding the absence of diffusion restricted in the majority of cases with spondylodiscitis (14patients; 10 of them were proved to be TB spondylodiscitis on follow up), while the remaining 4patients were proved to be pyogenic spondylodiscitis on follow-up.

In current study the abnormal signal on DWI was sub-divided into 4 patterns (definite claw sign, probable, questionable and diffuse signal intensity), thepresence of definite claw sign was seen in 19 of 36 patients (52.8%) with Modic 1, this was in agreement with Patel KB et al [19]and Muñoz et al [21]studies.

In this study we found that the probable claw sign seen in 10 patients of36 (27.8%) patients with Modic1, this was in agreement with Patel KB et al [19].

Questionable claw sign in this study was observed in 6 patients of 36(16.7%) with Modic1, this also was in agreement with Patel KB et al [19].

The last pattern of diffusion abnormality which was identified in this study was the diffuse signal (negative claw sign) observed in 4 (7.5%) of 53patients, 3 of them proved to be spondylodiscitis, this findings was lower than that observed in Patel et al [19]study, this difference may be explained by the fact that most spondylodiscitis cases in this study were proved to be TB rather than pyogenic spondylodiscitis which show no restriction abnormality on DWI (as mentioned previously) and matched to the result of Madhok et al [20]study.

Contrast enhancement of the disks and endplates proved to be indeterminate findings, as reported in previous studies [22]. At least some contrast enhancement of the vertebral endplates was seen in all cases but did not help to differentiate infection from degeneration. Contrast enhancement of the disk itself was seen slightly more frequently in infected disks (25%–30%) than in degenerative disks (11%–17%), but it was not a distinguishing feature [23].

In this study the Post contrast enhancement of intervertebral disc was positive among 11(30.6%) patients with Modic 1 changes and 16 (94.1%)patients with spondylodiscitis, while it was negative among 25(69.4%) patients with Modic changes and 1(5.9%) patient with spondylodiscitis and the sensitivity, specificity and accuracy rate of IVD enhancement in diagnosis of spondylodiscitis were 94%, 69% and 77% respectively, this was similar to results of Ledermann HP et al[24] that found the sensitivity, specificity and accuracy rate were 82%, 85% and accuracy of 81% respectively.

In this study, the sensitivity for each finding (definite, probable and questionable) were 52.8%, 27.8% and 16.7% respectively and specificity was100% for all findings. Combining the 3 findings (definite, probable and questionable) increase the sensitivity of Modic1 to 97.2%, these results were matched with the results of Patel KB et al [19] study.

CONCLUSION:

DWI is useful for differentiating Modic type 1 degenerative changes and infectious spondylodiscitis. The Claw sign is useful and accurate sign for distinguishing Modic type 1endplate degenerative changes from spondylodiscitis.

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