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RESEARCH ARTICLE

ACCURACY OF MAGNETIC RESONANCE IMAGING IN DIAGNOSIS OF VERTEBRAL LESIONS COMPARED TO PERCUTANEOUS BIOPSY

Prof. Hassan, A. Al-Naffakh and Lina Mohsin Rida

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Abstract

Objective: To evaluate the accuracy, sensitivity, and specificity of various MRI features in diagnosis of neoplastic and non neoplastic vertebral lesions including vertebral compression fractures caused by malignancy, osteoporosis, or infection, in correlation with true cut biopsy.

Methods: Retrospective review of MRI spine images of (28) patients (18 males and 10 females), age ranged 22 to 80 years (mean: 52.8±14.07 years), who had vertebral lesions and compression fractures, sent by their neurosurgeon and musculoskeletal specialists; for a diagnostic CT guided per-cutaneous biopsy between January 2013 to September 2013 to be carried out by a specialist expert radiologist. The MRI features are assessed and the sensitivity, specificity, and accuracy for each MRI feature was calculated and compared to histopathological results.

Results: Eighteen out of 28 patients had malignant vertebral lesions and 10 patients had benign vertebral lesions; 5 patients had osteoporotic compression fracture and 5 had infection. MRI features suggestive of malignant lesions were diffuse replacement of bone marrow signal in the affected vertebra; convex posterior border; pedicle and posterior neural element involvement; an epidural mass; a paraspinal mass; and multifocal vertebral lesions. MRI features suggestive of osteoporotic fractures are, fluid sign; a low signal intensity band; retropulsion; and spared normal marrow signal intensity. MRI features suggestive of infective lesions are, end plate disruption; disc involvement; contiguous vertebral involvement; paraspinal abscesses; and epidural abscesses. The overall sensitivity, specificity, and accuracy of MRI features were (94.4%, 100% and 96.4%) respectively as compared to percutaneous biopsy results. Vertebral morphology as vertebral body expansion is specific but non sensitive for malignant lesions; while compression fracture, focal abnormal signal intensity , and contrast enhancement are not useful for differentiation benign from malignant vertebral lesions.

Conclusion: Certain MRI features can accurately distinguish malignant from benign vertebral lesions and compression fracture.

Corresponding Author:- Prof. Hassan

Introduction:-

Magnetic resonance imaging is method of choice for evaluating patients with spinal complaints[1,2]. It has an integral role in characterization of marrow lesions, planning for biopsy or surgery, and post-treatment follow-up. A number of pathologic processes including vertebral compression fracture cause alterations of the normal vertebral body signal intensity recorded with magnetic resonance imaging . Vertebral collapse as a result of osteoporosis, infection or malignant disease either primary or secondary are common[3]. Attempts for accurate differentiation between neoplastic and non-neoplastic vertebral compression fractures maybe difficult[4]. This is especially true in elderly patients, who are predisposed to senile osteoporosis and malignant disease as well as their liability for spondylodiscitis[4,5,6]. Symptoms and signs of these types of fracture may be non specific and the only complaint of most patients may be back pain[4,6]. Since the prognosis and management differs in these three entities, accurate diagnosis is important[3,7], especially in patients with known non-osseous malignancies[8]. Imaging and biopsies of the spine are crucial in making a correct diagnosis[9]. The radiologist should review the clinical data and all imaging studies to ensure that a biopsy is indicated and to determine the most appropriate biopsy site. In complex-shaped bones, such as, the spine, CTS has allowed safe and accurate biopsy of osseous lesions throughout the spine, obviating invasive open biopsy in most cases.

Material and Methods:-

A retrospective cross-sectional study was carried out from January 2013 to September 2013. A population of 28 patients (18 males and 10 females) with vertebral lesions, with suspected primary and secondary malignant vertebral tumors ,vertebral spondylodiscitis and those who were complaining from compression vertebral fracture; were sent by their neurosurgeon and musculoskeletal specialists; for a diagnostic CT guided per-cutaneous biopsy. Patients with no or minor trauma (e.g. fall from standing height) were included. Plain films , CTS and MRI images were already have been completed and reviewed by a specialist expert radiologist prior to biopsy to be done by him [10]. All clinical data and laboratory parameters, especially prothrombin time (PT) and international normalized ratio (INR) were obtained. Patient's conventional MRI images were obtained from 1.5-tesla imagers (Acheiva MR-Philips) and (Avanto MR 2010-Siemens). The scanning sequences were as follows; Sagittal T1and T2-weighted spin echo, axial T2-weighted spin echo and T1-weighted in sagittal plane that was obtained after intravenous administration of gadolinium-diethylene triamine pentaacetic acid (Gd-DTPA) and reviewed retrospectively by two specialist radiologists in order to assess the MRI characteristic features of the vertebral lesions, which include (1) bone marrow replacement: whether complete (diffuse) replacement (hypointense on T1, hyperintense T2), or round / irregular foci of marrow replacement [11,12,13,14,15,16], (2) vertebral expansion[10],(3) vertebral compression fracture (decrease in vertebral height of 20—25 percent or more, or a decrease of at least 4 mm compared with baseline height)[8,18], (4) convex posterior vertebral border[8],(5) pedicle and posterior element involvement[8],(6) multifocal vertebral lesions(other metastases)[8],(7) retropulsion of a posterior bone fragment (often postero-superior angle of the vertebral body into the spinal canal)[19],(8) a low signal intensity band–like area on T1- and T2-weighted images corresponding to a fracture line or trabecular impaction[16,19,20], (9) a fluid sign: focal, linear or triangular areas of high signal intensity adjacent to the vertebral end plates on T2-weighted[16,19,20],(10) contiguous vertebral involvement[4,21],(11) vertebral end plate integrity[4,21],(12) vertebral disc involvement, manifest as an abnormal signal intensity pattern (hypointense on T1-weighted images and hyperintense on T2- weighted and post-contrast enhancement images) , reduced disc height[4,21],(13) epidural mass (anterior,posterior or encasing); and (14) a paraspinal soft-tissue mass[12,63],(15) a paraspinal abscess; and (16) an epidural abscess. Both abscesses and soft-tissue masses exhibit low signal intensity on T1-weighted images and high signal intensity on T2-weighted images, but soft-tissue masses are enhanced by Gd-DTPA whereas abscesses show ring enhancement[4,21]. All patients signed a written informed consent for CT guided biopsy after the procedure was clarified to the patients and their families. The procedures was done using a sixty four -slice CT scanner (Aquillon 64, V4.51 ER 010, Toshiba Medical Systems, Tochigi, Japan). Aspiration biopsy was performed with a (18-gauge) spinal needle while core biopsy was performed with a beveled tip (14-gauge) bone biopsy needle. The entry site for biopsy was the intersection of the long axis of the pedicle with the skin surface using a posterior approach, and 5—10 ml of local anesthetic (2% lidocaine,) was administered with 22- Gauge needle, attached to a 10-cc syringe [22,23] prior to the procedures.The sensitivity, specificity, and accuracy for each MRI feature were calculated. Associations between each MRI feature and various underlying vertebral lesions and compression fractures pathologies were evaluated using the Chi squared test. A p value of <0.05 was considered statistically significant[15].

Results:-

The study included 28 patients, 18 were males and 10 were females. The age range was 22 to 80 years(mean: 52.8±14.07 years), table (1). All cases were confirmed by CT guided percutaneous biopsy. Diagnoses of vertebral lesions based on MRI were: (27) correct cases, and only one incorrect case due to a malignant lesion . Diagnoses of vertebral lesions based on CTGPCB were: 18 (64.29%) patients (12 males and 6 females) had malignant vertebral lesions and 10 (35.71%) patients (6 males and 4 females) had a non-malignant vertebral lesions. The causes of benign (non malignant) vertebral lesions and compression fractures were osteoporosis (5 patients, 2 males and 3 females) having and infection (5 patients , 4 males and 1 female). Causes of malignant vertebral lesions are shown on (table 2) MRI characteristic findings of benign and malignant vertebral lesions are summarized in (Table 3).

Table 1:- Age distribution of the study group.

Pathology	N	Age/year (Mean± SD)	Mean	Std. Deviation	*P* value
Malignant	18	23-78	53.4444	13.00779	0.568
Osteoporosis	5	22-80	56.6000	21.51279	
Infection	5	37-63	47.2000	9.78264	
Total	28	22-80	52.8929	14.07214	

Table 2:- Tumor diagnoses of 18 patients presented with 64 malignant vertebral lesions and compression fractures.

2 (11.1%)	7	1
1 (5.6%)	4	1
2 (11.1%)	8	2
2 (11.1%)	11	2
1 (5.6%)	3	1
2 (11.1%)	3	1
8 (44.4%)	28	5
18(100%)	64	13

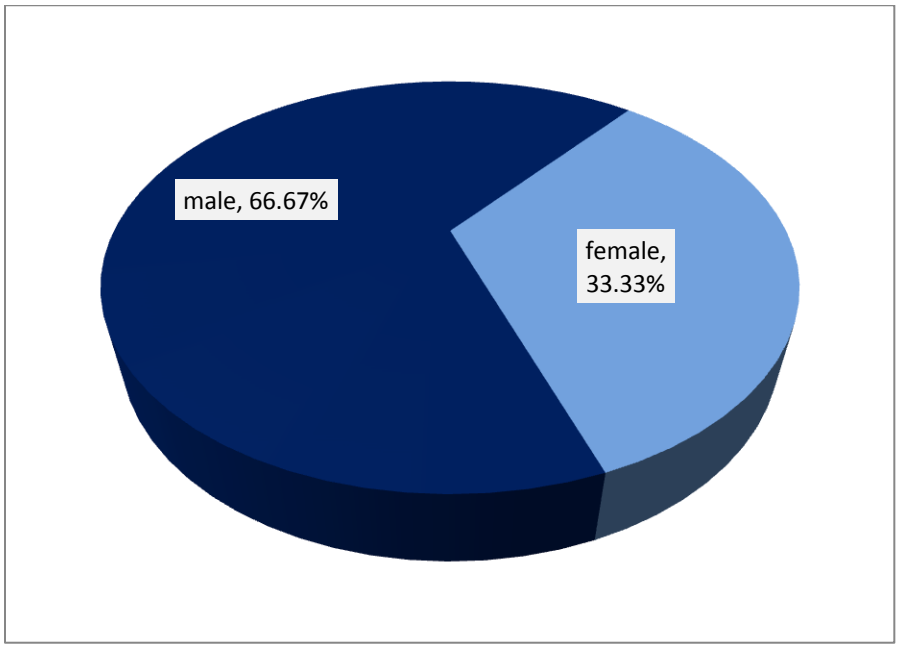

Figure 1:- Sex distribution of patients with malignant vertebral lesions.

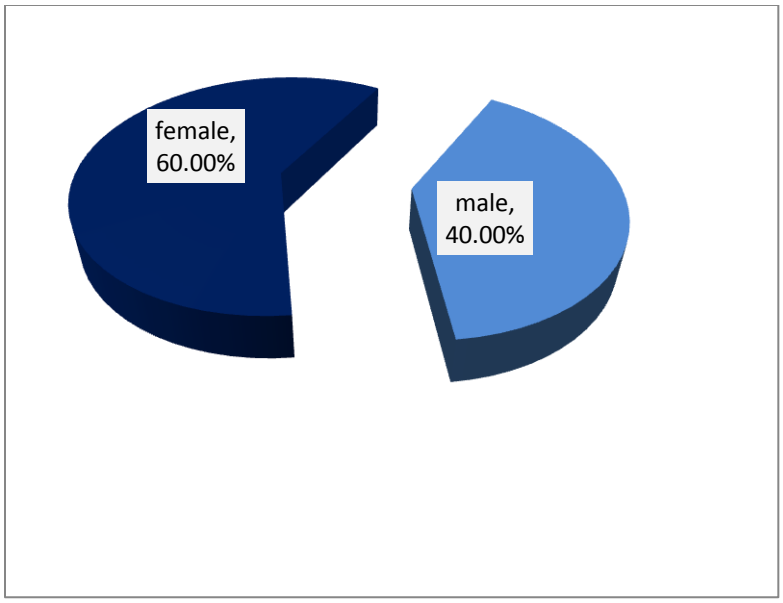

Figure 2:- Sex distribution of patients with osteoporosis.

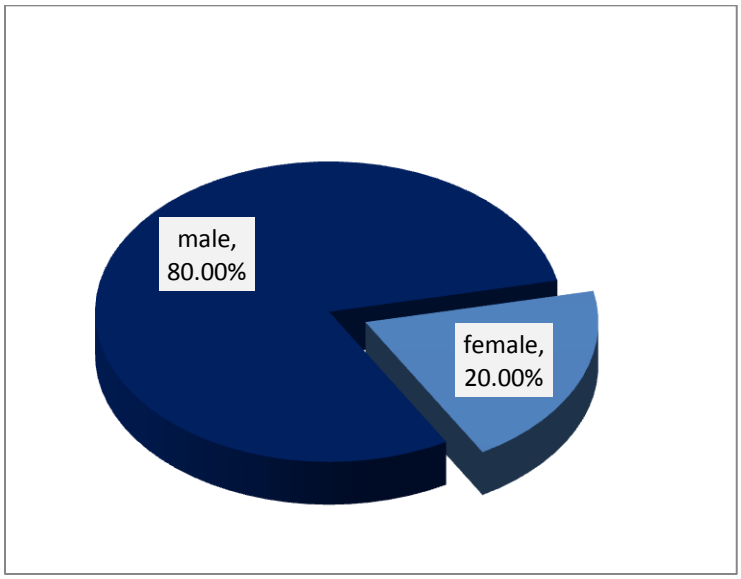

Figure 3:- Sex distribution of patients with infection.

Table 3:- Validity of different MRI criteria in diagnosing malignant and benign 83 vertebral lesions.

MRI	Malignant (n=64)	Osteoporo-sis (n=6)	Infection (n=13)	P value	Sensitivity	Specificity	Accuracy
Malignant features							
Diffuse abnormal SI (hypointense T1, hyperintenseT2)	37(57.8%)	0(0%)	2(15.4%)	0.001	57.8%	89.5%	65.1%
Abnormal vertebral SI Isointense to low on T2	24(37.5%)	2(33.3%)	3(23.1%)	0.08	37.5%	73.7 %	45.7%
Convex posterior border(fractured v.)	12/13(92.3%)	0(0%)	0(0%)	<0.001	92.3 %	100 %	96.2%

Convex posterior border(non-fractured v.)	31(48.4%)	0(0%)	0(0%)	0.003	48.4%	100%	60.2%
Pedicle involvement	63(98.4%)	1(16.7%)	4(30.8%)	<0.001	98.4%%	73.7 %	92.8%
Epidural mass	22(34.4%)	0(0%)	0(0%)	0.017	34.4%	100 %	49.4%
Paraspinal mass	32(50 %)	1(16.7%)	0(0%)	0.020	50 %	94.7%	60.2%
Multifocal vertebral lesions (other metastases)	60(93.8%)	0(0%)	2(15.3%)	<0.001	93.8%	89.5%	92.8%
Vertebral body expansion	16(25%)	0(0%)	0(0%)	0.078	25%	100 %	43.2%
Osteoporotic compression fracture features							
Low signal intensity band on T1 and T2	1(7.7%)	6(100%)	0(0%)	<0.001	100%	95 %	96.2%
Fluid sign	0(0%)	5(83.3%)	0(0%)	<0.001	83.3%	100%	96.2%
Normal remaining bone marrow in signal intensity	1(7.7%)	6(100%)	4(57.1%)	<0.001	100%	75%	80.8%
Retropulsion	1(7.7%)	5(83.3%)	0(0%)	<0.001	83.3%	95%	92.3%
Infective features							
End plate destruction	0	0	12(92.3%)	<0.001	92.3%	100%	98.8%
Contiguous vertebral involvement	6(9.4%)	0	13(100%)	<0.001	100%	91.4%	92.8%
Disc involvement	0	0	12(92.3%)	<0.001	92.3%	100%	98.8%
Epidural abscess	0	0	5(38.5%)	<0.001	38.5%	100%	90.4%
Paraspinal abscess	0	0	9(69.2%)	<0.001	69.2%	100%	95.2%
Features shared by all vertebral lesions							
Malignant compression fractures	13 (20.3%)	6(100%)	7 (53.8 %)	0.441	65.6%	10.5%	53%
Osteoporotic compression fracture	13 (20.3%)	6(100%)	7 (53.8 %)	0.105	100%	31.2%	36.1%
Infective compression fracture	13 (20.3%)	6(100%)	7 (53.8 %)	0.241	84.6%	31.4%	39.8%
MRI	**Malignant (n=64)**	**Osteoporo-sis (n=6)**	**Infection (n=13)**	**P value**	**Sensitivity**	**Specificity**	**Accuracy**
Features shared by all vertebral lesions							
Focal abnormal SI	27(42.2%)	6(100%)	11(84.6%)	0.451	42.2%	69.6%	35%
Contrast enhancement	57(89.1%)	5(83.3%)	13(100%)	0.233	89.1%	5.3%	69.9%
SI v.	Signal intensity Vertebra						

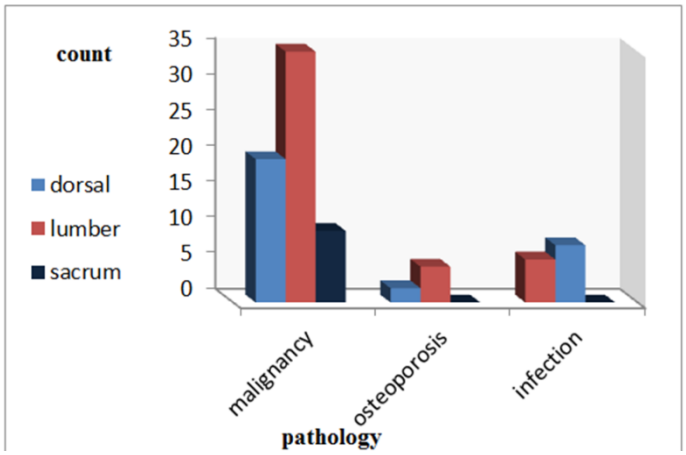

Figure 4:- Location of vertebral lesions.

Discussion:-

Up-to-date, it is accepted that MR imaging is far superior to other diagnostic tools [8,13—16 ,24,25] in distinction between malignant and benign vertebral lesions based on vertebral morphology, intensity of signal changes of bone and adjacent tissues and contrast enhancement characteristics.. The sensitivity, specificity, and accuracy for malignant lesions in this study were (94.4%, 100% and 96.4%) respectively. The overall diagnostic accuracy was comparable with that in previous reports in which the sensitivity, specificity, and accuracy were 100%, 93%, and 95%[8]; 85%–100%[24]; 79%–100%[25] and 86%–95%[26] respectively. However, only a few studies reported the sensitivity, specificity, and accuracy of each feature[8,15,16], which enable the surgeon to prioritize the MRI features in case of contradiction. Compared to a study in 2009[16], this present study comprised a 83 of vertebral lesions including compression fracture vs. 58 of compressed (fractured) vertebrae. The vertebral lesions in our study were classified into 3 categories (malignancy, osteoporosis, and infection), rather than 2 (malignant vs. benign) categories, in which their benign category (23 patients) included trauma and infection. Furthermore the malignant vertebral lesions were due to metastases as similar as some other studies [4,8], while we included both primary and secondary vertebral malignant tumors. In another study in 2011[15] higher number of vertebrae were studied, and also was confined only to vertebral compression fractures (152 vs 83 of total vertebral lesions) , the vertebral lesions were classified similar to our study into 3 categories (malignancy, osteoporosis, and infection), but the final diagnosis in our study, was totally based on biopsy, compared to 75% in their study and 22% regarding the former[16]. Because the accuracy of percutaneous vertebral biopsy was reported to be 80 to 90%[27], 68% to 97%[28,29]and the reported diagnostic accuracy of core biopsy ranges from 77 to 97% [30]; our study should be considered accurate, as diagnoses of all patients were made by percutaneous biopsy. Convex posterior border (Fig. 5). was the most reliable finding in this study in the diagnosis of malignant compression fracture, with high accuracy (96.2%) which is almost comparable with previous studies[8,15,16,19] shown on (table 4). On other hand Charles *et al* suggested that this finding was suggestive, but not specific for malignant nature. Fluid sign (fluid signal intensity located adjacent to the end plate) and low-signal-intensity band (Band like low signal intensity on T1- and T2-weighted images corresponding to a fracture line or trabecular impaction) were the most accurate signs helpful in differentiating non-malignant from malignant fracture (Fig. 6). Hong *et al* reported a sensitivity and specificity in diagnosis of MRI in spine infection of (96%) and (92%) respectively. End plate disruption and disc involvement were the most accurate and specific MRI features suggestive of infective lesions in this current study(Fig. 7), and it agreed with ME Abdel-Wanis *et al*[15]results, table (4).

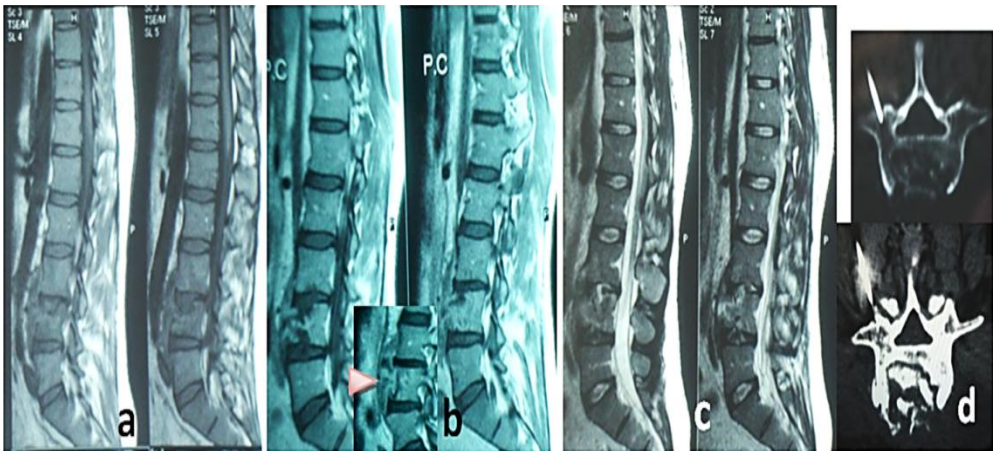

Figure 5:- MRI of the in a 47-year-old man convex posterior border (arrow)and multifocal lesions affecting dorsal and lumber vertebrae (arrowheads). Final Dx Ws multiple myeloma.

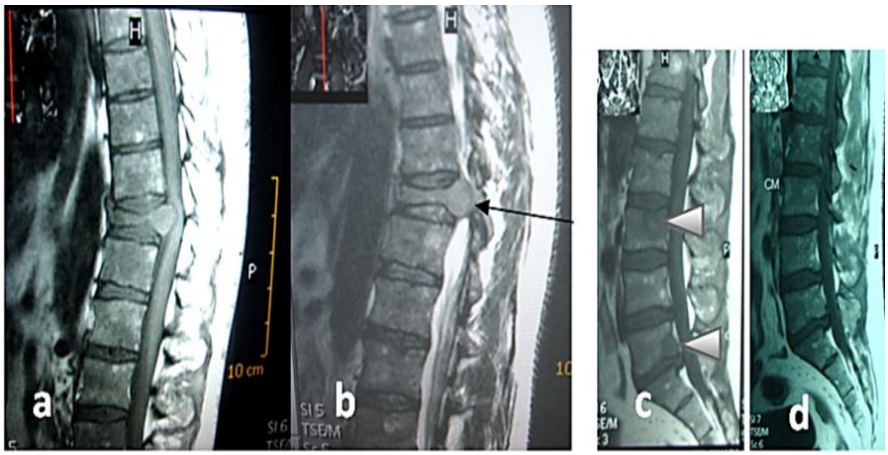

Figure 6:- MRI of the lumbosacral spine in a 65-year-old woman, there is a compression fracture of L3 that shows anterior wedging of the vertebral body, low signal fracture line(black arrow head), retropulsion of a posterior-superior bone fragment (pink arrow head), fluid sign(arrow).

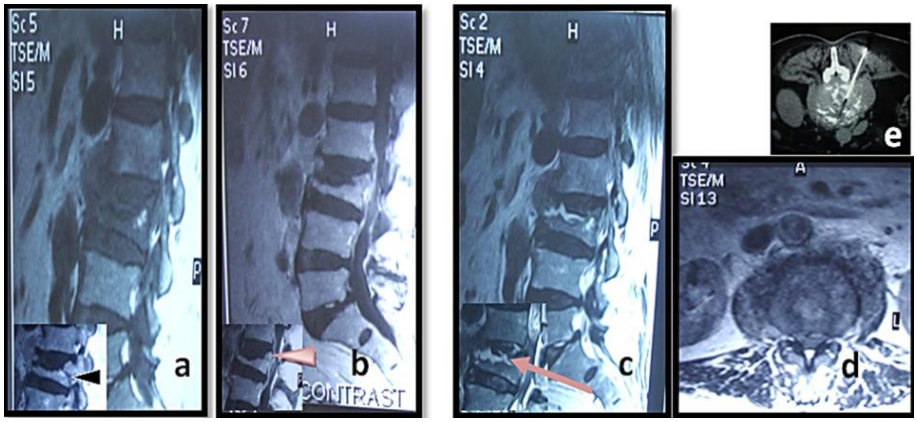

Figure 7:- MRI of the lumbosacral spine in a 45-year-old man, a compression fracture , endplated disruption, L4 L3/L4 intervertebral disc involvement, and a para-veretbral collection(abscess- arrow head) beneath the anterior longitudinal ligment.(d)CGPCB: transpedicular approach, using 18 gauge spinal needle.Diagnosis : spondylidiscitis

MRI Features		The Current study	Study 1 Tsai-Sheng et al[12]	Study 2 Jung et al [15]	Study 3 ME Abdel-Wanis et al[57]	
						Features suggestive of malignancy
Convex posterior border of the vertebral body.	Sensitivity	92.3 %	85.4%	74%	71%	**71 %**
	Specificity	100 %	------	80%	99%	**95.7%**
	Accuracy	96.2%	------	78%	83%	-----
	P value	<0.001	0.042	<0.001	<0.0001	**<0.001**
Diffuse replacement of bone marrow signal in the affected vertebra.	Sensitivity	57.8%	------	81%	------	------
	Specificity	89.5%	------	------	------	------
	Accuracy	65.1%	------	------	------	------
	P value	0.001	------	------	------	------
Pedicle and posterior element involvement.	Sensitivity	98.4%	94.75%	85%	95%	**91.4%**
	Specificity	73.7 %	-----	-----	70%	**82.6%**
	Accuracy	92.8%	-----	-----	84%	-----
	P value	<0.001	< .0001	<0.005	<0.0001	**<0.001**
Multifocal vertebral lesions (other metastases)	Sensitivity	93.8%	------	63%	77%	------
	Specificity	89.5%	------	95%	100%	------
	Accuracy	92.8%	------	84%	87%	------
	P value	<0.001	------	<0.001	-	------
Epidural mass.	Sensitivity	34.4%	------	74%	60%	**74.3%**
	Specificity	100 %	------	------	100%	**73.9%**
	Accuracy	49.4%	------	------	78%	-----
	P value	0.017	------	<0.001	-	**<0.001**
Paraspinal mass.	Sensitivity	50 %	95.8%	41%	80%	**71.4%**
	Specificity	94.7%	-----	93%	87%	**78.3%**
	Accuracy	60.2%	-----	75%	83%	-----
	P value	0.020	< .0001	<0.001	<0.0001	**<0.001**
						Features suggestive of osteoporotic fracture
Fluid sign	Sensitivity	83.3%	------	------	35%	**17.4%**
	Specificity	100%	------	------	98%	**82.6%**
	Accuracy	96.2%	------	------	84%	**----**
	P value	<0.001	------	------	<0.0001	**0.202**
Low signal intensity band.	Sensitivity	100%	------	93%	82%	------
	Specificity	95 %	------	56%	92%	------
	Accuracy	96.2%	------	80%	90%	------
	P value	<0.001	------	0.0004	<0.0001	------
Spared normal marrow signal intensity.	Sensitivity	100%	------	85%	79%	**52.2%**
	Specificity	75 %	------	81%	90%	**47.8%**
	Accuracy	80.8%	------	84%	88%	**-----**
	P value	<0.001	------	<0.001	<0.0001	**<0.001**
Retropulsion	Sensitivity	83.3%	------	60%	53%	**8.6%**
	Specificity	95%	------	89%	98%	**91.3%**
	Accuracy	92.3%	------	70%	88%	**-----**
	P value	<0.001	------	<0.001	<0.0001	**0.153**
						Features shared by all vertebral lesions
Focal abnormal	Sensitivity	42.2%	68.8%	------	------	**71.4%**

SI	Specificity	69.6%	-----	------	------	**34.8%**
	Accuracy	35%	-----	------	------	------
	P value	0.451	0.936	>0.05	------	------
Contrast enhancement	Sensitivity	89.1%	100%.	96%	------	-----
	Specificity	5.3%	-----	------	------	-----
	Accuracy	69.9%	-----	------	------	-----
	P value	0.233	0.0058	>.05	------	-----
Infective features						
End plate disruption	Sensitivity	92.3%	------	------	82%	------
	Specificity	100%	------	------	97%	------
	Accuracy	98.8%	------	------	93%	------
	P value	<0.001	------	------	<0.0001	------
	MRI Features	**Current study**	**Study 1 Tsai-Sheng et al** [12]	**Study 2 Jung et al**[15]	**Study 3 ME Abdel-Wanis et al**[57]	Study 4 Pongpornsup et al[58]
						Infective features
Contiguous vertebral involvement	Sensitivity	100%	------	------	88%	------
	Specificity	91.4%	------	------	73%	------
	Accuracy	92.8%	------	------	76%	------
	P value	<0.001	------	------	<0.0001	------
Disc involvement	Sensitivity	92.3%	------	------	97%	**34.8%**
	Specificity	100%	------	------	98%	**65.2%**
	Accuracy	98.8%	------	------	98%	-----
	P value	<0.001	------	------	<0.0001	**0.002**
Epidural abscess	Sensitivity	38.5%	------	------	73%	------
	Specificity	100%	------	------	100%	------
	Accuracy	90.4%	------	------	94%	------
	P value	<0.001	------	------	-	------
Paraspinal abscess	Sensitivity	69.2%	------	------	85%	------
	Specificity	100%	------	------	100%	------
	Accuracy	95.2%	------	------	97%	------
	P value	<0.001	------	------	-	------

Table 4:- Comparison between the current study and the most recent studies regarding sensitivity, specificity, accuracy and p-value in MRI findings.

Conclusion:-

MRI was a reliable method to differentiate between benign and malignant lesions and compression fractures.

Recommendations:-

A more formal prospective study with a larger number of patients is needed to confirm these findings.

1. As interpretation of MR images was performed by one experienced radiologist, interobserver variability and accuracy for less experienced radiologists are needed to be assessed.
2. The study relied on hard copies MR images due to lack of archiving system, which should available for research purposes .
3. This study recommend utilizing new MRI techniques as diffusion- weighted (DW) sequence , which is a useful method in differentiating malignant from osteoporosis compression fracture.

References:-

1. Bhatia RG, Sklar EML, Ruiz A, et al: Vertebral and paravertebral abnormalities. Clinical Magnetic Resonance Imaging, 3rd edition, Saunders-Elsevier, Philadelphia, 2006,pp 2313-56.

2. James SL and Davies AM: Imaging of infectious spinal disorders in children and adults. Eur J Radiol 2006; 58:27-40.
3. Fatima M. and Waseem A. Acute vertebral compression fracture: Differentiation of malignant and benign causes by diffusion weighted magnetic resonance imaging. JPMA 2011; 61:555—558.
4. Tsai-Sheng Fu, Li-Hui Chen, Jen-Chung Liao, et al. Magnetic Resonance Imaging Characteristics of Benign and Malignant Vertebral Fractures. Chang Gung Med J 2004;27:808-15. Rolf S., Harald S., Gerd F., et al: Current Diagnosis and Treatment of Spondylodiscitis .Dtsch Arztebl Int 2008; 105(10): 181–7.
5. Pradesh K. and Fiona W., Percutaneous biopsy in suspected infective Discitis. RAD Magazine 2010; 426 (36), 13-14.
6. Curtis W. Hayes,Mary E. Jensen, William F. Conway, et al. Non-neoplastic lesions of- vertebral bodies: Findings in magnetic resonance Imaging. RadioGraphics 1989 ;[9]:883-903.
7. Hee-Sun Jung, Won-Hee Jee, Thomas R. McCauley, et al. Discrimination of Metastatic from AcuteOsteoporotic Compression Spinal Fractures with MR Imaging. RadioGraphics 2003; (23):179—187.
8. R.Bender Ignacio, Anne Y Liu, Aliyah R Sohani, et al. Hodgkin's lymphoma masquerading as vertebral osteomyelitis in a man with diabetes. Journal of Medical Case Reports 2010; 4:102 .
9. WCG Peh. CT-guided percutaneous biopsy of spinal lesions. biij 2006; 2(3):25. Rupp RE, Ebraheim NA, Coombs RJ. Magnetic resonance imaging differentiation of compression spine fractures or vertebral lesions caused by osteoporosis or tumor. Spine 1995;20:2499–504.
10. Yuh WT, Zachar CK, Barloon TJ, et al. Vertebral compression fractures: distinction between benign and malignant causes with MR imaging. Radiology 1989;172:215–8.
11. Cuenod CA, Laredo JD, Chevret S et al. Acute vertebral collapse due to osteoporosis or malignancy: appearances on unenhanced and gadolinium-enhanced MR images. Radiology 1996; 199:541–9.
12. Conor D Collins. Multiple myeloma. International Cancer Imaging Society (2004); (4: 47–53).
13. ME Abdel-Wanis, Mohamed Tharwat, Mahmoud Solyman et al. Sensitivity, specificity and accuracy of magnetic resonance imaging for differentiating vertebral compression fractures caused by malignancy, osteoporosis, and infections. Journal of Orthopaedic Surgery. Sohag, Egypt.2011;19(2):145-50.
14. Pongpornsup S, Wajanawichakorn P, Danchaivijitr N. Benign versus malignant compression fracture: a diagnostic accuracy of magnetic resonance imaging. J Med Assoc Thai 2009;92:64–72.
15. Rajendra Kumar, R. David, Ali Shirkhoda et al. Expansile bone lesions of the vertebra. RadioGraphics 8: 749-769, July, 1988.
16. Eastell R, Cedel SL, Wahner HW, et al. Classification of vertebral fractures. J Bone Miner Res 1991;6:207–215. Uetani M, Hashmi R, Hayashi K. Malignant and benign compression fractures: differentiation and diagnostic pitfalls on MRI. Clin Radiol 2004;59:124–31.
17. Baur A, Stabler A, Arbogast S, et al. Acute osteoporotic and neoplastic vertebral compression fractures: fluid sign at MR imaging. Radiology 2002;225:730–5.
18. Vaccaro AR, Shah SH, Schweitzer ME, et al. MRI description of vertebral osteomyelitis, neoplasm, and compression fracture. Orthopedics 1999;22:67–73.
19. Orlando O., Gregg H. Zoarski, Allan L. Brook et al. Image-Guided Spine Interventions: Image-Guided Percutaneous Spine Biopsy. Springer Science + Business Media 2010 ;Chapter 5, 75-106.
20. Wen-Ching H. and Kun-E. Lim.Computed Tomography-guided Percutaneous Transpedicular Biopsy of the Thoracic Spine. Biij, 2001; 24: 368- 74.
21. An HS, Andreshak TG, Nguyen C, et al. Can we distinguish between benign versus malignant compression fractures of the spine by magnetic resonance imaging? Spine 1995; 20:1776–1782. Shih TT, Huang KM, Li YW. Solitary vertebral collapse: distinction between benign and malignant causes using MR patterns. J Magn Reson Imaging 1999; 9:635–642.
22. Frager D, Elkin C, Swerdlow M, et al. Subacute osteoporotic compression fracture: misleading magnetic resonance. Skeletal Radiol 1988; 17:123–126.
23. Nourbakhsh A, Grady JJ, Garges KJ. Percutaneous spine biopsy: a meta-analysis. J Bone Joint Surg Am 2008;90:1722–5.
24. Hau A, Kim I, Kattapuram S, et al. Accuracy of CT-guided biopsies in 359 patients with musculoskeletal lesions. Skeletal Radiol 2002;31:349–53.
25. Apoorva G., Wilfred C.G.,et al: Image-Guided Musculoskeletal Biopsy .Radiol Clin N Am 46 (2008) 455–473.
26. Schweitzer ME, Gannon FH, Deely DM, et al. Percutaneous skeletal aspiration and core biopsy: complementary techniques. Am JRoentgenol 1996;166:415–418.