Med. J. Cairo Univ., Vol. 91, No. 2, June: 659-665, 2023
www.medicaljournalofcairouniversity.net

Diagnosis of Different Spinal Lesions by Multi Parametric MRI

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Abstract

Background: Vertebral marrow lesions in patients with known primary malignancy are a common clinical problem, particularly in elderly patients. In spite of osteoporosis being the commonest cause at this age, the spine also is a common site of metastases, with about 39% of all bone metastases occurring in the spine. Such metastases may result in a pathologic fracture. Recently, multi-parametric MR imaging (mp MRI) has shown the ability to localize, detect, and stage various diseases.

Aim of Study: Assess role of Diffusion Tensor Imaging and in phase / opposed phases in diagnosis of different spinal bony lesions.

Patient and Methods: This prospective study was performed between December 2020 and December 2022 on patients who had spinal bony lesions of both sexes (47 patients; 29 males and 18 females). Only those patients who are willing to participate in study were included. All patients subjected to conventional MRI, DTI, In phase/Opposed phase imaging, FA, MD of malignant and benign lesion were calculated, signal characters in chemical shift images was estimated and subjected for statical analysis.

Results: ROC curve analysis revealed that FA cut-off value of 0.550 can differentiate malignant from benign lesions, with sensitivity, specificity and Accuracy of 87.5%, 65.2%, 76.6% respectively. Also MD cut-off value of 0.919 differentiate malignant from benign lesions with sensitivity, specificity, and Accuracy of 95.8%, 91.3%, 93.6% respectively. In out of phase images: Malignant lesions included in the study had high SI in 91.7% of them which is statistically significant (p<0.001) from benign lesions which showed signal drop in 87% of them.

Conclusion: However, conventional MRI is the imaging modality of choice in detecting and evaluating spinal bony lesions, advanced imaging techniques as DTI and in phase /out of phase images add more accuracy in differentiation and characterization of them.

Key Words: *Spinal Lesions – DTI – Chemical shift.*

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Introduction

THE spine is the largest store of bone marrow in the body. Addressing bone marrow signal pattern is an integral part of the spinal magnetic resonance (MR) imaging evaluation. By far, magnetic resonance imaging (MRI) is the best imaging modality to depict bone marrow thanks to its inherent soft-tissue contrast and non-ionizing nature **[1]**.

Vertebral marrow lesions in patients with known primary malignancy are a common clinical problem, particularly in elderly patients. In spite of osteoporosis being the commonest cause at this age, the spine also is a common site of metastases, with about 39% of all bone metastases occurring in the spine. Such metastases may result in a pathologic fracture **[2]**.

MRI is an excellent non-invasive modality for evaluating bone marrow and detecting marrow lesions. MRI has the highest sensitivity for detecting both diffuse and focal bone marrow involvement. In spite of its high sensitivity, MRI is of only limited specificity in the evaluation of bone marrow alterations. This limited specificity requires additional, sometimes invasive diagnostic steps to obtain accurate diagnosis **[3]**.

Recently, multi-parametric MR imaging (mp MRI) has shown the ability to localize, detect, and stage various diseases **[4,5]**. The mp MR in approach combines anatomic sequences (T1- and T2-

Abbreviation:

AUC : Area under Curve.
DTI : Diffusion tensor imaging.
DWI : Diffusion weighted imaging.
FA : Fractional anisotropy.
MD : Mean diffusivity.
MP : Multi parametric.
ROI : Region of interest.
ROC : Receiver operating characteristic.

weighted MR imaging) with functional imaging sequences. Functional and quantitative MR imaging methods, such as DWI, dynamic contrast-enhanced MR imaging, and in-phase/opposed-phase imaging, measure the Brownian motion of water molecules, regional vascular properties of the tumor, and fat quantification, respectively **[6,7]**.

DTI is a sensitive probe of cellular structure that works by measuring the diffusion of water molecules. The measured quantity is the diffusivity or diffusion coefficient, a proportionality constant that relates diffusive flux to a concentration gradient **[8]**.

Chemical-shift or opposed phase imaging relies on the fact that water and fat have different resonance frequencies so that when they are resonating aligned their signal is summed (in-phase imaging) while when they are opposed (out-phase imaging) their signals are subtracted with subsequent signal drop. As fat and water intermix in both types of marrow, the signal of red marrow will not significantly drop in out phase while that of yellow marrow will. However, this is not absolute and a cut off value of 20% signal drop has postulated **[1]**. In-phase/opposed-phase imaging of the spine should be a sensitive and specific way to differentiate benign from malignant lesions **[9]**.

Patients and Methods

This prospective study was performed on 47 patients (18 females and 29 males) between December 2020 and December 2022 in the Diagnostic Radiology Department of Mansoura University Hospital. Adult patients who had spinal bony lesions of both sexes.

I- *Inclusion criteria:*

- Only those patients who are willing to participate in the study will be included.
- Patients who diagnosed by previous imaging to have spinal bony lesions or pathologically proved spinal bony lesions.

II- *Exclusion criteria:*

1- Patients who have cardiac pacemaker, cochlearimplant, intracranial metallic aneurysmal clips, metallic FB in their eye and sever claustrophobic

2- Methods of research: All patients were subjected to full history taking & general and Neurological examination by the referring Department, then conventional non contrast MRI scan using 1.5 Tesla scanner (Ingena, Philips) in supine position with magnetic bore using body coli, the standard sequences obtained were:

1- T 1 (repetition time (TR)=400 ms, echo time (TE)=8ms, matrix=169, field of view (FOV) =422, slice thickness=4mm).

2- T2 (TR=3000ms, TE=120ms, matrix=169x169, FOV=422, slice thickness=4mm).

3- STIR (TR 2500ms, TE 40ms, matrix 269x384, FOV 500mm, slice thickness 6mm).

4- Then Diffusion tensor imaging was obtained using a Single shot echo planar imaging sequence (TR/TE=3200/90ms) with parallel imaging Sensitivity Encoding (SENSE) reduction factor P 2. Automatic multiangle-projection shim and chemical shift selective fat suppression technique applied to reduce the artefacts at diffusion-weighted MR images. Diffusion gradients were applied along 32 axes, using a b-value of 0 and 1000 s mm-2. The scanning parameters were: FOV=422mm^2, data matrix =88 and 28 slices were obtained, with a thickness of 4.4mm, with no gap and the total scan duration was 7-8min.

Then DTI Analysis was performed after the images were transferred to the workstation. Using View Forum 7.2.0.1 exported patient image data, Philips medical system, Best, Netherlands. Automated registration of the diffusion tensor imaging data was done to eliminate eddy current artifacts.

A region of interest (20-40 mm^2) was placed at co-registered FA map using an electronic cursor on the lesion of interest within vertebral body, FA and MD were automated calculated.

5- Lastly In phase/Opposed phase imagingwith In phase: TR 400, TE 4.6, FA 80, slice thickness 4mm, slice gap 1mm & Opposed phase: TR 400, TE 2.3, FA 80 slice thickness 4mm, slice gap 1mm. Signal changes of the lesions of interest within affected vertebral bodies were classified as bright intermediate of low signal in and opposed phase images.

N.B: All sequences were taken in sagittal plane on the affected vertebrae.

Statistical analysis:

Data analysis was performed by SPSS software, version 25 (SPSS Inc., PASW statistics for windows version 25. Chicago: SPSS Inc).

Ethical consideration:

- Study protocol was submitted for approval by Mansoura medical research ethics committee (our institutional research board "IRB"), Faculty of Medicine, Mansoura University.

- Code number: MS.20.05.1136.
- Informed consent will be obtained from each participant in the study after assuring confidentiality.
- Personal privacy will be respected in all levels of this study.

Final diagnosis based on clinical and radiological data, typical Hemangiomas with characteristic high T1 and T2 signalwith partial or total signal drop in STIR, infection: Diagnosed clinically by history, imaging methods and confirmed by laboratory findings after collection aspiration,vertebral compression: Known case of osteoporosis, compression fracture diagnosed by recent post traumatic history, multiple myeloma diagnosed by biopsy, metastasis with known cases of primary lesion and bone scan.

Results

The mean age of the 47 patients with benign lesions was (38.17±18.98) and the males (73.9%) more affected than females (26.1 %). And the mean age of patients with malignant lesions was (48.21± 14.31) with equal percentage of affection in both sexes (50%). Table (1) shows the distribution of benign and malignant lesions among included cases, 23 patients with benign lesions, 24 cases with malignant lesions. (Figs. 1,2).

Malignant lesions included in the study have low T1 SI in 87.5% which is statistically insignificant from benign lesions which showed low SI inT1WI in 73.9% of them. Also, Malignant lesions included in the study had high T2 SI in 54.2 % of them which is statistically significant (p=0.016*) from benign lesions which showed high SI inT2WI SI in 47.8% of them. In STIR and in phase images: No statistical significant as regard SI of benign and malignant lesions.

In out of phase images: Malignant lesions included in the study had high SI in 91.7% of them which is statistically significant (p<0.001) from benign lesions which showed signal drop in 87% of them (Table 2).

The mean FA for benign lesions was (0.456± 0.177) and for malignant lesions was (0.75±0.135) with statistically significant (p<0.001) and the mean MD for benign lesions was (1.36±0.34) and for malignant lesions (0.394±0.248) with statistically significant (p<0.001) Table (3) and Fig. (3).

ROC curve analysis revealed that by using cut-off value of 0.550 to differentiate malignant lesions from benign lesions FA had sensitivity, specificity, +ve predictive, –ve predictive and Accuracy of 87.5%, 65.2%, 72.4%, 83.3%, 76.6% respectively. And by using cut-off value of 0.919 to differentiate malignant lesions from benign lesions MD had sensitivity, specificity, +ve predictive, –ve predictive and Accuracy of 95.8%, 91.3%, 92%, 95.5%, 93.6% respectively.

From we realized that combined FA and MD had sensitivity, specificity, +ve predictive, -ve predictive and Accuracy of 95.8, 95.7, 95.8, 95.7, 95.7 respectively.

Table (1): Distribution of the studied cases according to diagnosis.

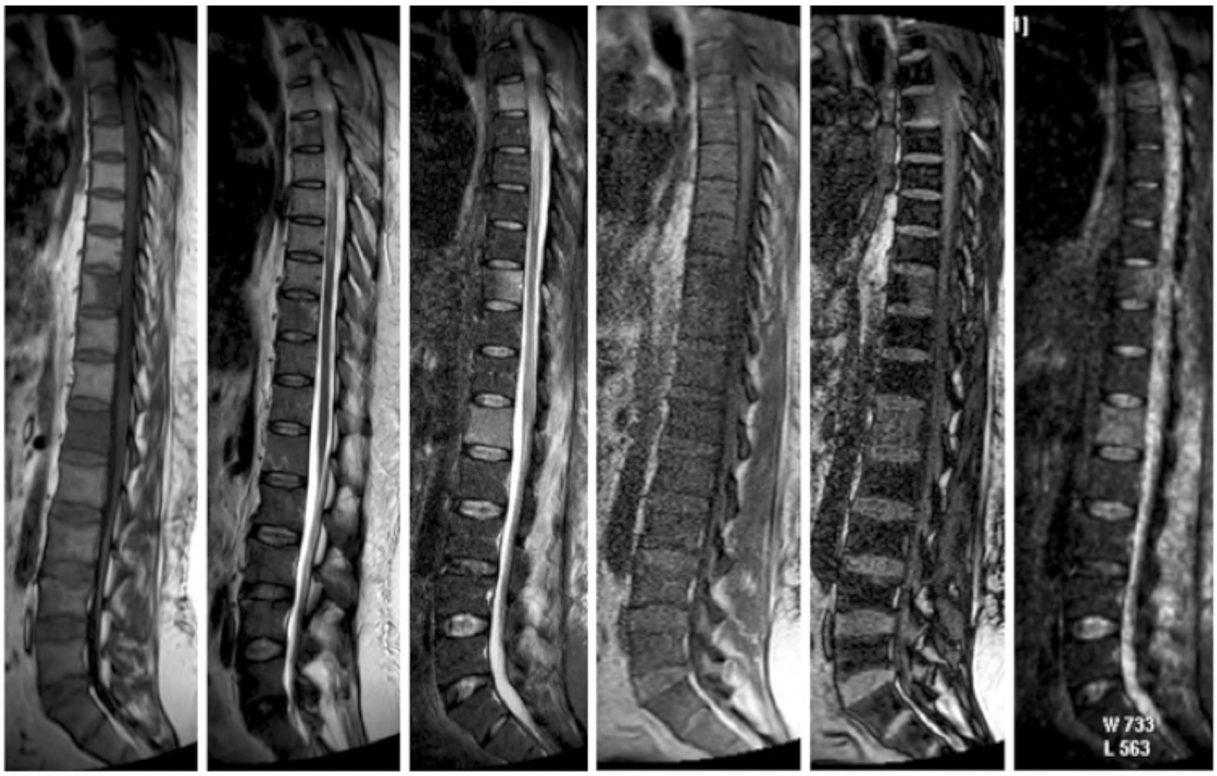
Diagnosis of benign:	N=23 (100%)
Vertebral compression	14 (60.9)
Vertebral compression fracture	5 (21.7)
Hemangioma	2 (8.7)
Infection	2 (8.7)
Diagnosis of malignant:	N=24 (100%)
Metastasis	18 (75)
Multiple myeloma	5 (20.8)
Lymphoma	1 (4.2)

Table (2): Comparison of MRI findings between benign & malignant lesions.

	Benign n=23 (%)	Malignant n=24 (%)	Test of significance
T1:			
Iso	2 (8.7)	1 (4.2)	MC=1.4
Low	17 (73.9)	21 (87.5)	p=0.496
High	4 (17.4)	2 (8.3)	
T2:			
Iso	7 (30.4)	2 (8.3)	MC=10.38
Low	2 (8.7)	9 (37.5)	p=0.016*
High	11 (47.8)	13 (54.2)	
Intermediate	3 (13.0)	0	
STIR:			
Iso	1 (4.3)	1 (4.2)	MC=3.36
Low	3 (13.0)	0	p=0.186
High	19 (82.6)	23 (95.8)	
Inphase:			
Iso	4 (17.4)	2 (8.3)	MC=3.78
Low	7 (30.4)	14 (58.3)	p=0.151
High	12 (52.2)	8 (33.3)	
Outphase:			
Low	20 (87)	2 (8.3)	FET=29.16
High	3 (13)	22 (91.7)	p<0.001 *

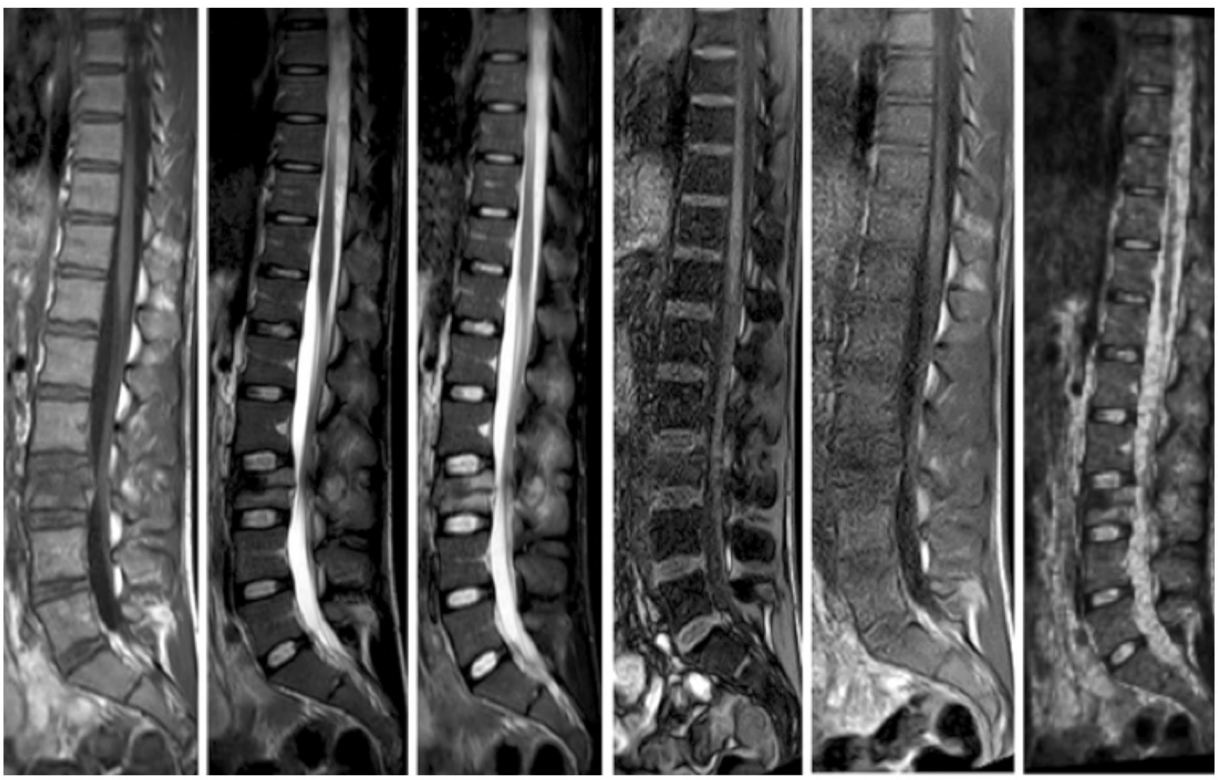
Table (3): Comparison of FA & MD between benign and malignant lesions.

	Benign n=23	Malignant n=24	Test of significance
FA:			t=6.38
Mean ± SD	0.456±0.177	0.75±0.135	p<0.001 *
MD:			t=11.03
Mean ± SD	1.36±0.34	0.394±0.248	p<0.001 *



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

Fig. (1): 65 years old femalepatient pathologically proved to have multiple myeloma, (A) T1, (B) T2, (C) STIR, (D) in phase, (E) opposed phase & (F) DTI with T2 mask images showing multilevel vertebral lesions with low T1, high STIR signal & no opposed phase signal drop.



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

Fig. (2): 18 years old male patient with L3 vertebral compression fracture, (A) T1, (B) T2, (C) STIR, (D), opposed phase (E) in phase & (F) DTI with T2 mask images showing L3 vertebral body low T1, high TSIR signal & opposed phase signal drop.

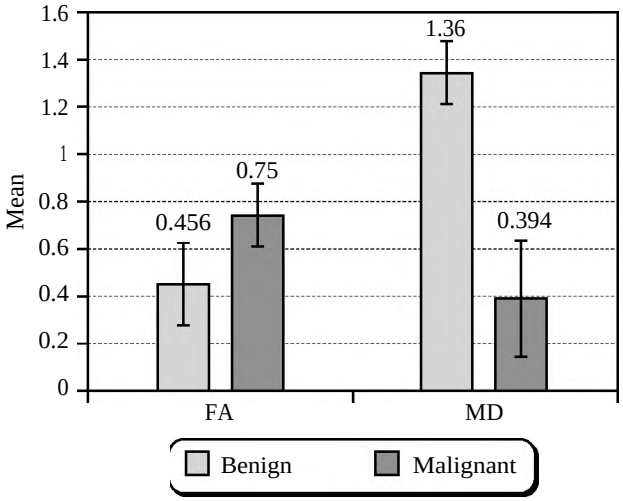


Fig. (3): Mean MD & FA between benign and malignant lesions.

Discussion

Vertebral marrow lesions are commonly seen in older age groups of patients, due to a variety of causes ranging from infections, traumatic collapse, osteoporotic collapse, and neoplastic vertebral marrow changes **[10]**.

MRI has the highest sensitivity for detecting both diffuse and focal bone marrow involvement. In spite of its high sensitivity, MRI is of only limited specificity in the evaluation of bone marrow alterations. This limited specificity requires additional, sometimes invasive diagnostic steps to obtain accurate diagnosis **[11]**.

The mean age of patients with benign lesions is (38.17±18.98) and the males more affected than females and the mean age of patients with malignant lesions is (48.21±14.31) with equal percentage of affection in both sexes while in the study of **[12]** the mean age of malignant lesions was 57±11.5 years, and that of benign lesions was 63±12.5 years.

Most of malignant lesions was metastases then multiple myeloma then lymphoma and this agree with previous study **[13]** in which most of vertebral lesions were metastases then multiple myeloma then lymphoma.

Most of benign lesions was compression then fracture then infection while in the study of **[14]** our study most of the malignant lesions appear low on T1WI, high on T2WI and STIR and this agreed with the study of **[15]** in which most of the suspicious lesions appearing low on T 1 W, high on T2W and STIR, explained by high cellularity and cytoplasmic fluid within malignant cells.

DTI is a non-invasive technique providing accurate imaging parameters that can be used for differentiating malignant from benign compressed vertebrae **[16]**. The principal finding in our study is that DTI parameters can be used for the differentiation of malignant and benign vertebral lesions. The FA of malignant vertebral bone marrow affection was higher than that of benign involvement and this cope with previous study **[16]** which found that mean FA values of malignant vertebral collapse of both readers were 0.55±0.2 and 0.52±0.1 and the FA values in patients with benign compressed vertebra of both readers were 0.26±0.1 and 0.28±0.1 respectively.

The AUC of FA was 0.902 and the cut off points for differentiating malignant from benign vertebral involvement were 0.550, While in the study of **[16]**. The AUC of FA was 0.93 and the thresholds of FA used for differentiating malignant from benign vertebral involvement of both readers were 0.37, and this differentiation may be due to different ROI size and machine parameters.

Not our study only but many studies approved that the FA values of malignant lesions are higher than that of benign lesions, other studies **[17,18]** in which the mean FA values of hepatic hemangiomas were significantly lower than those of malignant lesions & FA values of malignant lesions of parotid glands were significantly higher than those of benign lesions.

The mean MD values of benign vertebral involvement is higher than malignant vertebral involvement and this agree with previous study **[16]** which found that the mean MD values of malignant vertebral lesions were lower than benign vertebral lesions.

Many studies approved that the MD values of benign lesions are higher than malignant lesions on differentiation between benign and malignant head and neck as well as orbital tumors lesions using DTI and DWI **[16,19]**.

The addition of FA to MD calculation increased the confidence of prediction of nature of vertebral involvement. Previous study **[16]** which found thathigh AUC of combined FA and MD calculation with diagnostic accuracy of combined FA and MD calculation reaching 95.3%.

In-phase/opposed-phase imaging has been used extensively in separating benign from malignant adrenal lesions as well as differentiating fatty infiltration of the liver from neoplastic disease.

In-phase/opposed-phase imaging of the spine should be a sensitive and specific way to differentiate benign from malignant lesions **[20]**.

Of the 24 patients who proved to have malignant lesions, 22 showed no signal drop in out phase and only 2 showed signal drop. And of the 23 patients who proved to have benign lesions, 20 showed signal drop and only 3 show high signals and our results nearly similar previous studies **[21]**.

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تشخيص آفات العمود الفقرى المختلفة بإستعمال الرنين المغناطيسى

العمود الفقرى هو أكبر مخزن لنخاع العظام فى الجسم. تعتبر معالجة نمط إشارة نخاع العظم جزءاً لا يتجزء من تقييم التصوير بالرنين المغناطيسى للعمود الفقرى. يعد التصوير بالرنين المغناطيسى إلى حد بعيد أفضل طريقة تصوير لتصوير نخاع العظام بفضل تباين الأنسجة الرخوة المتأصل فيه وطبيعته غير المؤينة.

تشاهد آفات نخاع العمود الفقرى بشكل شائع فى الفئات العمرية الأكبر من المرضى، وذلك بسبب مجموعة متنوعة من الأسباب تتراوح من العدوى، والانهيار الرضحى، وانهيار هشاشة العظام، وتغيرات نخاع العمود الفقرى الورمى.

أجريت هذه الدراسة الاستباقية على ٤٧ مريضاً ممن يعانون من آفات عظمية فى العمود الفقرى. ٢٩ ذكور و ١٨ إناث وكان متوسط عمر المرضى المصابين بأفات حميدة بينما كان متوسط عمر مرضى الآفات الخبيثة (٤٨.٢١±١٤.٣١).

تم إحالة المرضى ممن يشتبه سريرياً أو إشعاعياً فى إصابة بالعمود الفقرى من أقسام طب الأعصاب وجراحة الأعصاب والأورام بمستشفيات جامعة المنصورة للتقييم الإشعاعى تم إجراء التصوير بالرنين المغناطيسى بتسلسلات مختلفة. وتم قياس معاملات الانتشار الموتر ثم تم التجزئة والمعالجة بواسطة تعلم الآلة لجميع الحالات.

كان عدد المرضى الذين يعانون من الآفات الخبيثة ٢٤ (١٨) ورم خبيث، ٥ ورم نقوى متعدد وورم ليمفاوى. (واحد) و كان عدد الآفات الحميدة ٢٣ (١٤) انضغاطاً فى العمود الفقرى، ٥ كسور فقرية، ٢ ورم و عائى وعدوى توجد دلالة إحصائية فى متوسط التباين الكسرى للآفات الحميدة والخبيثة حيث وجد أن متوسط التباين الكسرى للآفات الخبيثة أعلى من الحميدة كما أن القيمة الفاصلة للتباين الكسرى لها دور فى التمييز بين الآفات الخبيثة والحميدة.

كما توجد دلالة إحصائية فى متوسط معامل الانتشار للآفات الحميدة والخبيثة حيث وجد أن متوسط معامل الانتشار للآفات الحميدة أعلى من الآفات الخبيثة كما وجد أن القيمة الفاصلة لمعامل الانتشار أعلى من التباين الكسرى فى التمييز بين الآفات الخبيثة والآفات الحميدة مع حساسية ودقة عالية وأيضاً كان هناك دلالة إحصائية فى جمع معامل الانتشار والتباين الكسرى معاً فى التمييز بين نوعى الآفات.