

**Original Article, Oncology****A Comparison between FDG PET/CT, CT and MRI in Detection of Spinal Metastases and its Impact on Clinical Management****Wafaie, A<sup>1</sup>. El-Liethy, N<sup>1</sup>. Kassem, H<sup>2</sup>. and Kotb, M.H<sup>3</sup>.**<sup>1</sup> *Department of Radiology, Cairo University.* <sup>2</sup> *Department of Radiology, Benha University.* <sup>3</sup> *Department of Nuclear Medicine, National Cancer Institute, Egypt.***ABSTRACT:**

The aim of this study was to compare the diagnostic value of combined F-18-FDG PET/CT, CT and MRI in detection of spinal metastatic lesions and their impact on management of these patients. **Patients and methods:** A total of 22 patients with biopsy-proven malignancy were enrolled. All patients underwent spinal MRI and whole body F-18-FDG PET/CT examinations using standard techniques. The diagnostic capabilities of the imaging modalities were compared in the same spinal field of view. F-18-FDG PET/CT and MRI findings were compared with the results of biopsy or clinical / radiological follow up for at least 12 months as the reference standards. **Results:** A total of 214 vertebral lesions were detected in 22 cancer patients based on combined clinical and radiological follow up (FU), these lesions were divided into: 129 metastatic & 85 benign lesions. Moreover these 22 patients were divided into: 12 with spinal metastases and 10 free from spinal metastases. Both lesions & patients based data analysis showed a significant higher diagnostic accuracy for the combined F-18-FDG PET/CT (98.5% and 94.5%) compared to MRI (86% and 68%) and CT (79.5% & 54.5%) respectively

( $P < 0.05$ ). The significant difference between F-18 FDG PET/CT and morphological techniques were more obvious on specificity indices rather than sensitivity indices in both lesion and patient based analysis. On the other hand, MRI results were superior to those of CT on both lesions and patients data analysis. On lesion-based analysis, the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for F-18 FDG PET/CT were 99%, 98%, 98% & 99%, For MRI were 88.4%, 82.4%, 88.4% and 82.3%, and for CT were 83.7%, 73%, 82.4 and 74.5% respectively. On patient-based analysis the sensitivity and specificity for F-18 FDG PET/CT were 100% & 90% compared to 75% & 60% in MRI and 66.6% & 40% in CT ( $P < 0.05$ ). The relative superiority of the F-18 FDG based technique compared to the morphological techniques in respect to sensitivity and specificity provide significant changes in patient management in 27.2% & 41% of cases compared to MRI & CT respectively.

**Conclusion:** Combined F-18 FDG PET/CT scan showed the highest utmost sensitivity, specificity and accuracy followed by MRI and lastly CT in the

detection of spinal metastatic lesions. Consequently <sup>18</sup>F-FDG PET/CT has a

better impact on clinical management compared to MRI&CT.

**Keywords:** FDGPET/CT – MRI – Spine – Cancer.

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## INTRODUCTION:

The skeletal system, especially the spine, is a frequent target of metastatic spread from various primary tumors like carcinoma of the breast, lung and prostate. Moreover, primary malignancies may also originate from the bone marrow, such as lymphoma and multiple myeloma. Beside its poor prognostic aspect, spinal bone metastases cause serious significant cumulative morbidity including bone pain fractures, spinal cord compression and other nerve compression syndrome<sup>(1)</sup>. Proper evaluation of bone metastases and early detection of occult bone metastases is essential for correct treatment decision<sup>(1)</sup>. Overlapping benign vertebral lesions such as spinal degenerative changes, osteoporosis & collapse which are not uncommon in old age group of cancer patients may provide an additional challenging issue for detection of vertebral metastases<sup>(2,3)</sup>. Variable imaging tools are available for exploration of vertebral metastases including bone scan (BS), computed tomography (CT) and magnetic resonance imaging (MRI) with variable merits, advantages and limitations. The sensitivity of bone scan is unsatisfactory in detection of spinal lesions due to limited spatial resolution. CT enjoyed high spatial resolution that provide high yield in anatomical details, better detection of cortical based lesions as well as detection of soft tissue components of tumor involving the vertebral column<sup>(4,5)</sup>. On the

other hand unsatisfactory CT results are seen in detection of metastases associated with severe osteoporosis and marked degenerative changes as well as bone marrow based metastases<sup>(5, 6)</sup>. The high spatial and soft tissue contrast resolution of MRI escalate its sensitivity in early detection of bone marrow based and intra-medullary lesions and provide better differentiation between benign & malignant causes of cord and vertebral fracture compression. However MRI has a limited ability in detection of cortical based lesion & differentiation of osteomyelitis from vertebral metastases<sup>(6,7)</sup>. Finally morphological modalities suffer from limited ability in proper monitoring of response of vertebral metastases to variable therapeutic tools<sup>(4,5,6,7,8)</sup>. F-18 FDG has been established as a PET imaging tracer for the detection and monitoring of numerous malignancies owing to the increased glycolysis of most of tumor cells. However the results obtained investigating F-18-FDG PET in detection of bone metastases is conflicting with sensitivity varying widely from 56.5% to 100%. F-18-FDG PET is more sensitive in detecting lytic rather than sclerotic metastases due to its higher glycolytic activity and cellularity<sup>(9, 10, 11)</sup>. F-18 FDG provides early detection and better monitoring response to therapy for bone marrow based metastases compared to other diagnostic tools. False positive F-18 FDG results may occurs with

benign metabolically active lesions e.g. histiocytic or giant cell-containing lesions, inflammatory & infection as well as non-specific para-spinal muscle uptake. Moreover variable FDG uptake was noticed in degenerative spinal process. The availability of hybrid PET/CT enables us to correlate directly the F-18 FDG uptake features with CT morphology and this would ideally investigated by sequential F-18 FDG-PET/CT studies performed on the same patients treated during a certain time

## PATIENTS AND METHODS:

The study population comprised 22 patients with biopsy-proven malignancy. All patients underwent MRI of the spine and whole-body F-18 FDG PET/CT. The maximum elapsed time interval between both techniques did not exceed two weeks during which no therapy was given to the patients.

### **MRI Scanning:**

MRI studies were performed at 1 and 1.5 T (Intera and Achieva; Philips) along sagittal and axial planes. MRI sequences included T1, T2weighted turbo-spin-echo images and post contrast T1-weighted images (5 mins after intravenous administration of 0.1 mmol/g gadopentetatedimeglumine [Magnevist]; Schering).

### **FDG PET/CT Scanning:**

Combined PET/CT scan was performed using Siemens Biograph true V with a 64 multi-slice CT scanner. F-18 FDG-PET/CT was performed following intravenous administration of 5.5 MBq/Kg F-18 FDG with patient fasting for 6 hours. Serum glucose levels were lower than 150 mg/dl & images were acquired 90 minutes after tracer injection, while patient in supine

period. These significantly escalate the diagnostic accuracy & limit the causes of false positive results for F-18 FDG PET (12, 13, 14). The fore mentioned consideration encouraging us to perform the current prospective study aiming to compare the diagnostic value of F-18 FDG PET, CT, combined F-18 FDG PET/CT and MRI in detection of spinal metastatic lesions and the impact of F-18 FDG PET-CT on patient management.

position from the base of the skull to the mid-thigh region. A PET emission scan was performed over several bed positions (5to7) for 2 minutes per bed position with an axial field of view of approximately 21.6 cm per bed position & in-plane spatial resolution of 2 mm covering the same field of view as with CT. Diagnostic CT with contrast was performed using the following parameters; (350 mA, 120 KV, 0.5 second tube rotation time, slice thickness 5 mm, 8-mm table feed & 3 mm incremental reconstruction). Non-contrast CT was done in patient with impaired renal function (creatinine level >2 mg/dl) and/or has history of hypersensitivity for contrast media. To calculate maximal standardized uptake values (SUVmax), manually defined regions of interest (ROI) were drawn on the attenuation corrected emission image throughout the axial planes.

### **Image analysis:**

The PET/CT data were separated into PET and CT image sets. Two specialists, a radiologist and a nuclear medicine physician, performed an independent

interpretation of the CT and PET images. In a separate session afterward, the readers interpreted the combined PET/CT images in consensus. The MRI images of the patients were interpreted separately by two experienced radiologists working in consensus and were blind to the PET/CT findings. The whole FDG PET/CT and MRI findings were compared to the results of biopsy or clinical / radiological follow up for at least 12 months as the reference standards.

#### **F-18 FDG PET images:**

F-18 FDG PET images were assessed for presence or absence of osseous tumor deposits by using a five-point grading system in which the lesion uptake was compared to liver uptake (or blood pool in patients with liver disease) as follow:- score 0 (no uptake): the lesion was definitely negative ; score 1 (lesion uptake < liver uptake): the lesion was probably negative ; score 2 (lesion uptake = liver uptake): the lesion was equivocal; score 3 (lesion uptake slightly higher than liver): the lesion was probably positive; score 4 (intense lesion uptake that significantly higher than liver): the lesion was definitely positive.

#### **CT images:**

On CT, bone lesions were classified into benign & malignant according to their morphological appearance. Malignant lesions were suggested by the presence of lytic, sclerotic or mixed lytic-sclerotic intramedullary changes. Cortical disruption with or without extra osseous soft tissue component was considered sign of malignancy. Sclerotic changes close to end plates and lytic lesions with regular sclerotic margin close to facets and vertebral end plates were considered benign. Well defined osteolytic

lesions with vertical sclerotic striations (Polka dot sign of hemangioma) were also considered benign. Para-vertebral soft tissue masses, including epidural masses, or masses involving neural foramina were recorded. In case of vertebral collapse, associated medullary lytic lesions, para vertebral mass and abnormal contrast enhancement were considered signs of metastasis.

#### **Combined F-18 FDG PET/CT images:**

Combined F-18 FDG PET/CT images were assessed for presence or absence of spinal metastases by matching the level of FDG uptake using the fore mentioned five-point grading system with CT changes as follow:

#### **Concordant PET/CT changes:**

- 1-Malignant spinal lesion: - Grade 3,4 F-18 FDG uptake with malignant CT changes.
- 2-Benign spinal lesion: - Grade 0,1, 2 F-18 FDG uptake corresponding to definite CT benign changes.

#### **Discordant PET/CT:**

- 1-Malignant lesion:-Grade 3,4 spinal lesion without CT changes for malignancy.
- 2-Benign lesions:- Grade 0,1,2 corresponding to a suspicious CT changes for metastases.

#### **MRI Images:**

On MRI, marrow infiltrative lesions of abnormal signal intensity in T1 and T2 weighted images (especially in vertebral body and pedicles) and showing post contrast enhancement were considered positive for metastasis. Cortical disruption with or without extra-osseous soft tissue component was considered sign of malignancy. In case of vertebral collapse, associated medullary marrow signal infiltration, para vertebral mass and abnormal contrast enhancement were considered signs of metastasis. Marrow changes close to vertebral end plates and

facet joints (as part of spondylotic process) were considered negative.

Well defined lesions of high signal in both T1 and T2 (characteristic for hemangioma) were also considered negative for malignancy. Determination of true or false positive and/or negative lesions were based on biopsy (histopathological examination) as well as clinical and radiological follow for at least 12 months as follow: -

**True-positive:** Score 3–4 with or without radiological finding for metastases ,histopathologically was positive or progressed during follow.

**True-negative:** Score 0–2 concordant with negative radiological features for metastases. Histology was negative or examinations did not show progression during follow up.

**False-positive:** Score 3–4 discordant with negative radiological findings for

metastases, and histopathology were negative or it showed no progression at follow-up sessions.

**False-negative:** Score 0–2 discordant with positive radiological finding of metastases and histology was positive or follow-up examinations showed growth of the lesion(s).

### **Statistical analysis:**

Predictive values for different imaging tools were calculated using Wilson score which was generated by the open Epi-program .the significant of correlation was assessed with the Fisher Z test. The multiple comparisons were adjusted by using the Benferroni-Holm method. P values of less than 0.05 were considered to indicate significant difference.

## **RESULTS:**

The current study included 22 histopathologically proven cancer patients. There were 9 male and 13 female patients with mean age of 44 year  $\pm$  22. Histopathologically, the study included 7 breast cancers, 4 Hodgkin lymphoma, 3 Non-Hodgkin lymphoma, 2 rectal carcinoma, 2 bronchogenic carcinoma, 1 hepatocellular carcinoma and 1 patient had malignant neuro-endocrinal tumor. The remaining two patients had metastases of unknown primary. Comparing the results of all modalities, within the same field of view, revealed the following:

### **Metastatic lesion detection:**

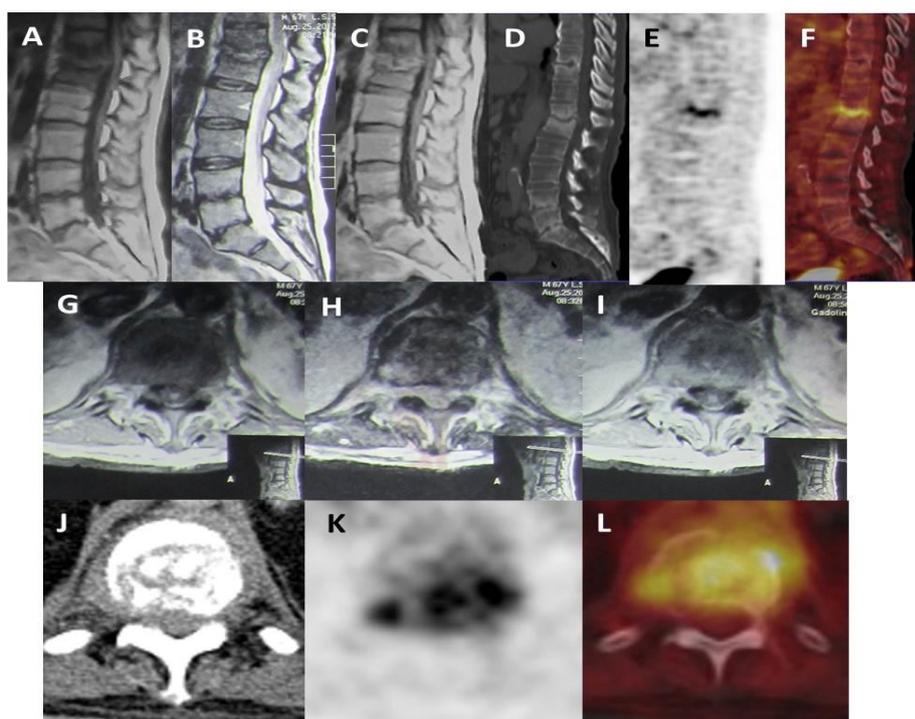
**Lesion-based data analysis:** A total of 214 vertebral lesions were detected in the current study. According to follow up period of at least 12 months, combined

radiological & histo-pathologically proven data, these lesions were divided into 129 metastatic lesions and 85 were of benign nature. All the bone lesions were separately analyzed on F-18 FDG PET/CT, CT as well as MRI and compared to clinico-radiological follow up data for at least 12 months &/or biopsy proven pathological data as a reference standard.

In attempt to explore the additive value of combined F-18 FDG PET/CT compared to F-18 FDG PET results without CT combination, the detection capability of both techniques were estimated and compared to FU clinic-radiological results (**Tables 1 and 2**). Based on the 5 point visual grading score, F-18 FDG PET divided the documented 214 lesions into 128 malignant & 86 benign lesions. According to follow up data, the F-18 FDG

PET detected 128 malignant lesions are divided into 120 true positive and 8 false positive lesions. On the other hand, the F-18-FDG PET detected 86 benign lesions were divided into 77 true negative and 9 false negative lesions. The 8 false positive F-18 FDG PET uptakes include (2 non-specific para-spinal muscular uptake, 2 nodal lesions, 1 spondylodiscitis and 3

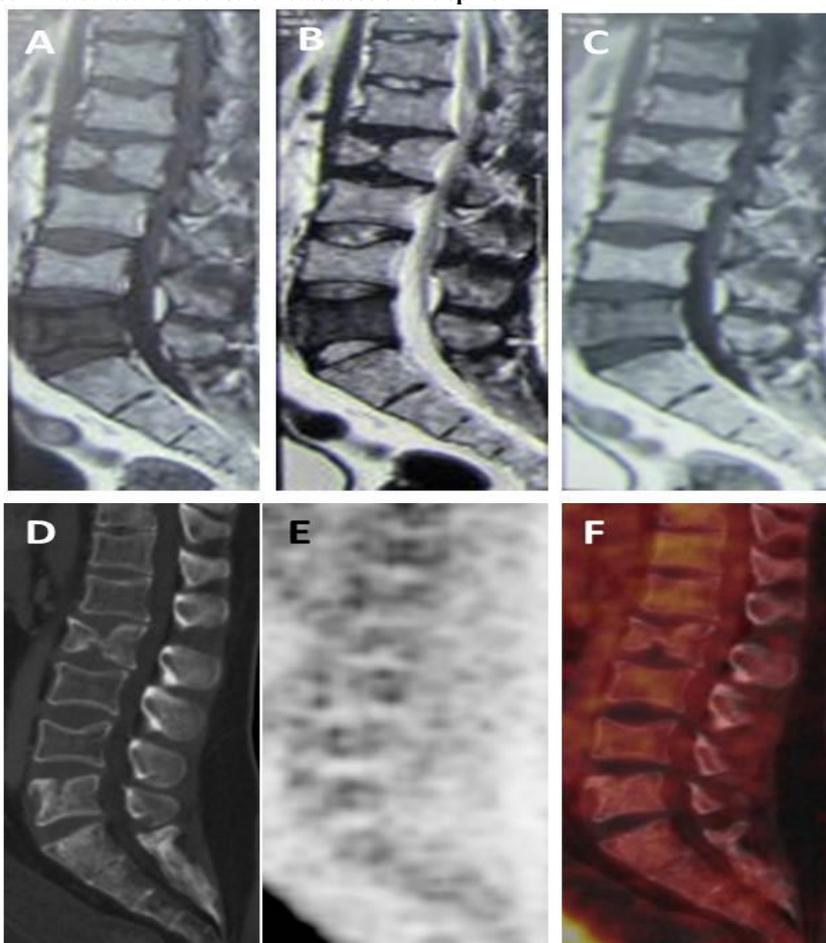
severe degenerative changes) (Figure1). Nine false negative irregularly sclerotic lesions with score 2 were missed by FDG PET that progressed during follow up. Therefore, F-18 FDG PET/CT had significantly additive value to F-18 FDG PET in respect to reducing false positive & false negative results. (Figures 2, 3).



**Figure 1:** A 66 year-old male presented with soft tissue metastatic deposits of unknown primary malignancy. MRI of lumbar spine (in sagittal and axial T1, T2 and T1 post-contrast, A, B, C, G, H, I respectively) showed spondylodiscitis of T12, L1 and the intervening disc with abnormally enhanced paravertebral and intraspinal epidural soft tissue component compromising the conus medullaris. CT (D and J) showed vertebral endplate erosions and reduced height of discs at T9-10, T12-L1, L4-5 and L5-S1 levels (multilevel spondylodiscitis) with no evidence of osteolytic lesion. FDG PET (E and K) showed focally increased uptake in upper lumbar region suspicious of active metastatic lesion. FDG PET/CT (F and L) showed increased FDG uptake of T12-L1 disc and adjacent vertebral endplates as well as accompanied paravertebral and intraspinal epidural soft tissue component denoting active spondylodiscitis. Diagnosis: active spondylodiscitis at T12-L1 with no metastatic deposits.



**Figure 2:** A 30 yrs-old female, with a history of left breast cancer, underwent left mastectomy followed by radiation and chemotherapy. MRI of dorsal and lumbar spine (T1, T2 and T1 post contrast, A to F) showed diffuse bone marrow infiltrative neoplastic lesions showing low signal in T1, intermediate to low signal in T2 with patchy contrast enhancement involving most of thoracic and lumbar vertebrae with associated pathological fracture of T11 vertebra. CT (G) showed multiple sclerotic deposits with pathological fracture of T11 vertebra. FDG PET (H) revealed multilevel metabolically active metastatic lesions of dorso-lumbar spine. FDG PET/CT (I) showed multiple disseminated metabolically active FDG avid sclerotic osseous lesions involving most of the vertebral column. **Diagnosis:** disseminated active sclerotic metastases of the spine.



**Figure 3:** A 26 yrs.-old male, with relapsed HD, received chemotherapy and underwent bone marrow transplantation. MRI (sagittal A, B and C) showed diffuse L5 vertebral marrow infiltration of low T1 and T2 signal intensity with post contrast enhancement. Anterior wedging of L2 with no underlying infiltrative marrow lesion. CT (D) showed patchy sclerosis of L5 and upper sacral segments. FDG PET and combined FDG PET/CT (E and F) were negative for abnormal FDG uptake. **Diagnosis:** complete disease remission.

**Table1: Correlation between F-18 FDG PET and clinical /radiological follow up results in 22 cancer patients: n= 214**

	FU True positive Spinal lesions(n)	FU True Negative Spinal lesions (n)	Total (n)
PET Positive lesions (n)	120	8	128
PET Negative lesions (n)	9	77	86
	129	85	214

\*FU : Follow up

**F-18-FDG PET/CT results:**

F-18 FDG PET/CT divided the documented 214 lesions into: 130 malignant and 84 benign lesions. Out of the F-18 FDG PET/CT detected 130 malignant lesions, there were two false positive lesions that showed severe degenerative changes with marked sclerosis and high grade FDG

uptake (score > 2) that remained stationary during follow up. On the other hand, out of the (84) F-18 FDG PET/CT suggested benign lesions there were single false negative lesion with low grade F-18 FDG uptake (less than 2) and limited sclerotic changes that progressed during follow up (**Table 2**).

**Table2: Correlation between F-18 FDG PET/CT and clinical /radiological follow up results in 22 cancer patients: n= 214.**

	FU True positive Spinal lesions(n)	FU True Negative Spinal lesions (n)	Total (n)
F-18 FDG PET/CT Positive lesions (n)	128	2	130
F-18 FDG PET/CT Negative lesions (n)	1	83	84
	129	85	214

\*FU: Follow up

**CT Results:**

Based on CT criteria, CT divided the 214 documented lesions into: 131 malignant and 83 benign lesions. According to the clinico-radiological follow up data, the CT depicted 131 malignant spinal lesions were classified into 108 true positive and 23 false positive lesions. On the other hand, the remaining 83 benign spinal lesions on CT

were divided to 62 true negative and 21 false negative (**Table 3**). The 62 benign lesions compromised 5 haemangiomas, 34 degenerative end plates changes and 17 degenerated facet joints, 2 pars inter-articularis breaks and 4 spondylodiscitis (one of them was associated with soft tissue component) (**Figure1**). Pathological

compression of the vertebral body was identified 9 out of the 108 (8.3%) CT detected malignant lesions. On the other hand, 17 compression fractures were

detected in seven patients, secondary to osteoporotic changes of the vertebral column (benign fractures) (**Figure 3**).

**Table3: Correlation between CT and combined clinical /radiological follow up results in 22 cancer patients: n= 214.**

	FU True positive Spinal lesions (n)	FU True Negative Spinal lesions (n)	Total (n)
CT Positive lesions(n)	108	23	131
CT Negative lesions (n)	21	62	83
Total (n)	129	85	214

\*n= number \*\*FU : Follow up

**MRI Results:**

MRI divided the 214 documented clinical and follow up lesions into 129 malignant and 85 benign lesions. In comparison to clinical and radiological follow up data, the MRI depicted 129 malignant spinal lesions

were classified as 114 true positive (Figure 2) and 15 false positive lesions (Figure 3) while the remaining 85 benign spinal lesions were divided into 70 true negative and 15 false negative (**Table 4**).

**Table 4: Correlation between MRI and combined clinical /radiological follow up results in 22 cancer patients: n= 214 .**

	FU True positive Spinal lesions (n)	FU True Negative Spinal lesions (n)	Total (n)
MRI Positive spinal lesions (n)	114	15	129
MRI Negative spinal lesions(n)	15	70	85
Total (n)	129	85	214

\*n= number \*\*FU: Follow

**Overall results of F-18, FDG PET/CT, CT and MRI:**

**Table 5** shows a comparison between the overall results of F-18 FDG PET/CT, CT and MRI based on biopsy results and/or combined clinical and radiological follow up. Based on the net results of false & true lesions in each technique the sensitivity, specificity, accuracy, PPV & NPV were

estimated for each technique. F-18 FDG PET/CT results exhibit the utmost high figures in the fore mentioned parameters that was clearly superior to MRI & CT results (P<0.05). CT had the lowest yield among the three assessed techniques.

**Table 5: Lesion- based comparison between F-18 FDG PET/CT, CT and MRI in detection of spinal metastases in 22 cancer: n=214.**

	F-18 FDG PET/CT (n)	CT (n)	MRI (n)
<b>True Positive (n)</b>	128	108	114
<b>False Positive (n)</b>	2	23	15
<b>True Negative (n)</b>	83	62	70
<b>False Negative (n)</b>	1	21	15
<b>Sensitivity (%)</b>	99%	83.7	88.4%
<b>Specificity (%)</b>	98%	73%	82.3%
<b>PPV (%)</b>	98%	82.4%	88.4%
<b>NPV (%)</b>	99%	74.5%	82.3%
<b>Overall Accuracy(%)</b>	98.5%	79.5%	86%

\*n= number \*\*PPV= positive predictive value \*\*\*NPV = Negative predictive value.

### Patient-Based Analysis:

According to clinico-radiological FU & histo-pathological biopsies, the 22 studied patients were divided into: 12 patients with spinal metastases and 10 patients free of spinal deposits. Patient based data analysis (**Table 6**) showed the utmost high F-18 FDG PET/CT results are remained. F-18 FDG PET/CT had better accuracy compared to MRI & CT as it eliminates their false positive more than false negative results. Therefore higher significant differences for specificity indices rather than sensitivity indices were demonstrated

when comparing F-18 FDG PET/CT with MRI. The lowest yield among the three assessed techniques was still noticed in the CT results. Accordingly, F-18 FDG PET/CT avoided further therapy in 3 & 6 patients compared to MRI and CT respectively. On the other hand, F-18 FDG PET/CT recommended further therapy for 3 & 4 patients compared to MRI & CT respectively. Therefore, F-18 FDG PET/CT changed management in 27.2% & 41% of cases compared to MRI & CT respectively.

**Table 6:- Patient- based comparison between F-18 FDG PET/CT, CT and MRI in correlation with FU data in detection of spinal metastases in 22 cancers.**

	F-18 FDG PET/CT	CT	MRI
<b>True Positive (n)</b>	12	8	9
<b>False Positive (n)</b>	1	6	4
<b>True Negative (n)</b>	9	4	6
<b>False Negative (n)</b>	0	4	3
<b>Sensitivity (%)</b>	100 %	66.6%	75%
<b>Specificity (%)</b>	90%	40%	60%
<b>PPV (%)</b>	92.3%	57%	69%
<b>NPV (%)</b>	100%	50%	89%
<b>Overall Accuracy (%)</b>	95.4%	54.5%	68%

\*PPV= positive predictive value \*\*NPV = Negative predictive value.

### Soft Tissue Abnormalities at the Vertebral Region:

Six of the 129 malignant lesions, detected in two of the 22 study patients, had associated para-spinal soft tissue masses. These lesions displayed epidural extension of tumor with neural foramen involvement. Subsequently, they were seen indenting the spinal cord/ thecal sac. Only one benign lesion showed soft tissue abnormality

accompanying vertebral involvement in one patient with multilevel spondylodiscitis (**Figure1**). It also elicited combination of intraspinal epidural and neural foramen involvement causing compression of the spinal cord and exiting nerve roots.

### DISCUSSION:

Bone metastases have important implications in terms of worsening morbidity and mortality of patients, as more than 2 out of 3 patients who die from cancer have bone metastases. Cancer cells are lodged in the bone marrow as the initial site for skeletal metastasis by means of hematogenous spread. Being rich in red marrow in adults, spine represents common targeted sites for metastases. The more frequent metastatic events, the weight bearing and protective function of spine for spinal cord, the associated spondylo-degenerative and osteoporotic changes as well as serious related morbidity events create a strong need for a highly sensitive and accurate diagnostic tool for early detection and accurate assessment of spinal metastases (8, 15, 16, and 17). Different diagnostic imaging tools are used to assess spinal metastases including F-18 FDG PET/CT, CT and MRI with variable success rate. The current study shows the superiority of F-18 FDG PET/CT compared to morphological imaging in detection of spinal lesions. CT is widely accepted in assessment of cancer patients because of its high spatial resolution that provide satisfactory anatomical details, better detection of cortical based lesions and associated soft tissue component. However many investigators show

unsatisfactory CT results in assessment of spinal metastases (17, 18, 19, 20). This low CT yield was attributed to many factors including: delayed diagnosis as considerable level of cortical destruction is required for visualization of metastases by CT, limited sensitivity in detection of metastases within a variety of osteoporotic & spondylo-degenerative changes and CT is not able to early detect bone marrow lesions. Moreover poor CT results were obtained in assessment of response of spinal metastases to therapy. In agreement with the fore mentioned data, the current study showed that CT had the lowest diagnostic efficiency compared to MRI and F-18 FDG PET/CT with statistically significant difference. Associated osteoporosis, old porotic fracture and inactive post therapy sclerosis for completely remitted lesions were the main reasons for such low CT diagnostic yield in the current study. In clinical practice MRI is widely used for assessment of spinal lesions with higher diagnostic yield compared to CT. This is attributed to its higher soft tissue contrast & better spatial resolution compared to CT. coinciding with that the current study showed superior MRI diagnostic efficiency compared to CT in the current study. On the other hand MRI results were significantly lower than F-18

FDG PET/CT ( $P < 0.05$ ). This is attributed to false positive results of MRI in cases of inactive completely remitted vertebral lesions and recent porotic collapse on top of degenerative changes. Moreover false negative MRI results were noticed in early developing cortical based lesions. These MRI limitations were successfully solved by F-18 FDG PET/CT in the current study (27, 28, and 29). F-18 FDG PET/CT has gained wide acceptance in clinical use in imaging algorithm of oncological patients with a special interest for exploration of spinal metastases. In this work F-18 FDG PET/CT provided the utmost diagnostic efficiency with variable significant higher difference in term of sensitivity, specificity, accuracy, PPV and NPV compared to MRI and CT. It should be noted that the significant difference between F-18 FDG PET/CT and the morphological techniques was more obvious on specificity indices rather than sensitivity indices in both lesion and patient based analysis. Early detection of bone marrow based lesions, less affected by osteoporotic and/or spondylo-degenerative changes and its more appropriate monitoring of lesion metabolic activity and response to therapy are attributed to the fore mentioned results regarding assessment of spinal lesions (21, 22, 23, 24, and 25). Moreover, this work showed the additive value of F-18 FDG PET/CT compared to F-18 FDG PET. The observed complementary effect of CT and F-18 FDG PET in assessment of spinal vertebral lesions limited the false positive and false negative results for either technique separately. In F-18 FDG PET/CT, the CT component provided better anatomical details with some specific structural changes that limited false positive F-18 FDG uptake (with specific benign structural changes e.g. spondylodiscitis &

improper uptake localization i.e. para-spinal uptake) and reduced false negative low grade FDG uptake in irregular sclerotic malignant lesions. On the other hand, the better sensitivity & specificity of F-18 FDG PET component reduce false negative CT results in detection of bone marrow based lesions, lesions associated with osteoporosis & severe degenerative changes as well as with post therapy sclerosis (26). Our data coincided with other authors who reported the higher diagnostic efficiency of complementary F-18 FDG PET/CT than isolated F-18 FDG PET & CT (23, 24, and 25). A major contribution of CT in F-18 FDG PET/CT studies is its complementary role in detection of soft tissue component of tumor involving the vertebral component. It has additional diagnostic impact, dire prognostic impact & serious morbidity (4, 8). Our study described soft tissue component in 6 malignant spinal lesions (4.7% of all malignant F-18 FDG PET/CT lesions) depicted in 2 of the study subjects compromising the spinal cord or thecal sac. On the other hand, only one benign soft tissue lesion was detected related to spondylodiscitis also compromising the spinal cord (**Figure 1**). These soft tissue components were detected by both CT and MRI. Detection of pathological fracture and differentiation of benign from malignant compression fracture is crucial clinically desired information. In this work CT was able to detect 26 pathological vertebral fractures but cannot differentiate benign porotic fracture from metastatic compression fractures in all cases (6). This issue was solved through monitoring of FDG uptake that was high in 9 malignant compression fractures, while no uptake was seen in 17 porotic fractures. Post therapy osteoblastic bone reaction is accompanied

by increasing sclerosis from periphery of the lesions inward on CT images (Figure3) that may falsely suggesting disease progression<sup>4</sup>. Similarly appearance of post therapy marrow necrosis in MRI may suggest presence of progressive metastatic lesions<sup>19</sup>. The current results are partially affected by the effect of therapy on the detected spinal lesions with false positive sclerotic CT changes & marrow necrosis in MRI. Fortunately, these false positive CT & MRI lesions were clarified by lacking of FDG uptake in F-18 FDG PET/CT in the current study.

#### **Changes in patient management:**

F-18 FDG PET/CT avoided unnecessary overtreatment in 3& 6 patients with false positive MRI & CT vertebral lesions. Moreover F-18 FDG PET/CT recommended further therapy in three and four patients with false negative MRI & CT vertebral lesions. Similar results were obtained by other authors<sup>(27, 28, 29)</sup>. The strength of the current study includes its prospective nature for addressing a

comparison between F-18 FDG PET/CT, CT and MRI in detection of vertebral metastases as well as assessment of their impact on patients' management. The limitations of the study lie in its running on a short term basis on a limited number of heterogeneous groups of patients with different age groups, pathology of primary malignancy, therapy & duration of disease.

#### **CONCLUSIONS:**

F-18 FDG PET/CT showed the higher sensitivity, specificity and accuracy in detection of spinal metastatic lesions, followed by MRI and lastly CT. Combined FDG PET/CT had a better clinical impact in respect to changing patient management compared to MRI & CT however it was more obvious on the latter. The complementary effect of F-18 FDG and CT in the co-registered combined F-18 FDG PET/CT seems to play a major role in such high diagnostic yield in detection & assessment of spinal metastases.

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