Original Paper, PET/CT.

How Hybrid PET/CT Improve Pitfalls and Artifacts in Malignant Lymphoma?

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ABSTRACT:

18F-FDG PET/CT has become a standard procedure for the evaluation of lymphomas. An understanding of the role of FDG PET/CT in the management of lymphomas and knowledge of its limitations is mandatory for the optimal utilization of this technique. The present study aimed to assist accurate interpretation with proper diagnosis by exclusion of false positive or false negative causes of PET/CT studies. **Material and Methods:** This retrospective study included 105 adult patients with malignant lymphoma to diagnose possible pitfalls during study interpretation. All clinical and histopathological information were extracted from the patients' clinical sheet. **Results:** The study included 105 patients (48patients with HD and 57 patients with NHL). The mean age of all patients was (46.78 ± 16.78) years. The majority of patients were males (61.9%); while (38.1%) were females. Total numbers of pitfalls detected were 373 sites. Physiological Pitfalls were detected in 71 sites, (36 sites had muscle uptake 12 sites had uterine-related uptake pitfalls, 12 sites had brown adipose tissue uptake and 5 sites had unilateral vocal cord uptake. Technical pitfalls were detected in 128 sites (50 sites had contrast-induced artifacts,41 sites had head movement, 36 sites had metallic artifact and one site showed truncation related pitfalls). Therapy related artifacts were detected in 156 sites (56 sites had gastric uptake. 54 sites had splenic & BM uptake and 30 patients had enhanced salivary uptake, while, 6 sites had diminished salivary uptake, 6 patients had thymic hyperplasia and 4 patients had early and late radiation effect).

Benign pathological benign conditions were detected in18 sites (9 sites had incidental thyroid uptake and 8 patients had inflammatory lung uptake and one patient had bone fracture).

Conclusion: PET/CT is a powerful imaging technique for characterizing pathological lymphomatous lesions with proper evaluation of physiological, technical and post therapy pitfalls or artifacts.

Key Words: Malignant Lymphoma & PET/CT & Pitfalls.

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INTRODUCTION:

Malignant lymphomas are a heterogeneous group of diseases in which treatment and prognosis depend on accurate subtype and staging. 18F-FDG PET scan has been found useful in the staging and follow-up of both Hodgkin's and non-Hodgkin's lymphoma. A meticulous evaluation of PET/CT findings, along with a detailed history, clinical examination, and knowledge of the histological type a pre-requisite to accurate interpretation. However, understanding of the role of FDG PET/CT in the management of lymphomas and knowledge of its limitations mandatory for the optimal utilization of this technique. Sites of high physiological uptake such as the brain, myocardium, gastrointestinal tract, urinary tract, lymphoid tissue and brown adipose tissue obscure or mimic the presence of tumor deposits [1, 2]. Benign conditions with increased glycolysis, such as infection, inflammation, and granulomatous disease, may also lead to increased FDG uptake, and be mistaken for lymphomatous deposits. Inflammatory changes secondary to surgery, radiotherapy, and chemotherapy may also lead to false-positive results, if the study is performed soon after these interventions [3, 4]. Bone marrow hyperplasia secondary to chemotherapy with or without cytokines, such as granulocyte colony-stimulating factor, may lead to increased FDG uptake up to 3 weeks after the last dose of cytokines similar effects can be seen in the spleen [5]. The use of combined PET/CT imaging system creates distinctive artifacts that are not seen on dedicated PET-only systems.

The most commonly seen artifacts are related to the use of CT data rather than PET data for attenuation correction [6].

Aim of the Work: Is to accurate interpretation of patients with false positive false negative lymphoma.

MATERIALS AND METHODS:

This is a retrospective study 105 adult (≥ 18 years) patients with malignant lymphoma presented to Maadi Military Hospital and International Medical Center during Jan 2014 to Dec 2018, to diagnose possible pitfalls during study interpretation. The protocol of the study was approved by the ethical committee in Oncology and Nuclear Medicine department in faculty of Medicine, Cairo University. All clinical and histopathological information were extracted from the in agreement with the referring physicians. This included the pathological data as well as timing of PET/CT imaging. **Patients:** We evaluated PET/CT scans from 105 adult patients with proved malignant lymphoma. All patients had PET/CT scan either for initial staging, therapy monitoring, post-therapy assessment or suspected relapse. Evaluation for pitfalls detected initially or after GSF therapy or chemotherapy, metal artifacts and post therapy changes correlated with clinical history and histopathological assessment, needed.

Technique of Whole-Body PET/CT Imaging with ^{18}F-FDG:

The physician evaluates the clinical history of the patient and any treatment given. The physician authorizes dose of ^{18}F-FDG, based on the patient's weight. Optimal imaging conditions can usually be achieved with normal blood glucose in patient's fasting for 6 to 8 hours. Good control of blood glucose is essential before imaging in diabetic patients to reach normal blood glucose. The patient is asked to remove metallic objects and instructed to avoid any kind of strenuous activity prior to the examination and following injection of the radioisotope to avoid physiologic muscle uptake of FDG. The patient is asked to void prior to scanning. Inject ^{18}F-FDG into the patient in a dosage of 0.1 mCi/kg or as prescribed by the physician the patient waits for 45 to 60 minutes after FDG administration and is instructed to remain quiet with minimal movement until the completion of the PET/CT scan.

Patient position and acquisition: PET/CT is performed on an integrated scanner dedicated PET-CT scanner (GE, PET CT Discovery)that combines both CT and PET capabilities in two sequential gantries, avoiding the need for patient motion between the CT and PET components of the study. The CT study takes approximately 60–70 seconds and the study comprises a multi detector CT examination from the base of the skull to the mid thighs (120 mA, 140 kVp, table speed = 13.5 mm per rotation).

PET is performed following the CT study without moving the patient. Approximately six to seven bed positions with 1 –2 minutes acquisition at each bed position. Attenuation correction of PET images is performed by using attenuation data from the CT component of the machine. Efforts are made to co register two sets of digital images. In co registration, the matrix size, voxel intensity, and the rotation are adjusted to establish a one-to-one spatial correspondence between the two images.

Imaging interpretations: Images were interpreted by 2 experienced nuclear medicine physicians. One of them had experience of 10 years and other had 8 years' experience in Nuclear Medicine Field.

Qualitative assessment for presence of hyper metabolic lesions was evaluated. All pitfalls including physiologic, technical, therapy related and benign lesions were evaluated in both PET, CT and fused images.

Semi-quantitative evaluation was performed using the Standardized Uptake Value (SUV_{Max}), of abnormal foci if needed.

Statistical Analysis: Data entry, processing and statistical analysis was carried out using Med. Calc. ver. 15.8. (Med. Calc, Ostend, Belgium).

Test of significance was used. Data were presented and suitable analysis was done according to the type of data (parametric and non-parametric) obtained for each variable. P-values less than 0.05 were considered to be statistically significant. Mean, Standard Deviation (± SD) and range for parametric numerical data, while Median and Inter-Quartile Range (IQR) for non-parametric numerical data, frequency and percentage of non-numerical data.

RESULTS:

This retrospective study conducted on 105 adult patients with Malignant Lymphoma (ML) to assess accurate interpretation with proper diagnosis by exclusion of false positive or false negative causes of PET/CT studies related to different types of artifacts.

Basic clinical data: The mean age of all patients was (46.78 ± 16.78) years. The majority of patients were males (61.9%); while (38.1%) were females. Regarding pathological type of lymphoma, (54.3%) of patients had NHL, while (45.7%) had HD ***(Table 1)***. Regarding timing of PET/CT, (20%) of patients was referred for initial staging PET/CT, (54.3%) had PET/CT at the end of therapy and (25.7%) had been referred for PET/CT for a suspected relapse **(Table 1).** Regarding pitfalls interpretation, 40 **(Table 1).**

Table 1: Patients in 105 patients of malignant lymphoma.

Variables		Number	Frequency
Sex	Male	65	61.9%
	Female	40	38.1%
Pathological Type	Hodgkins	48	45.7%
	Non-Hodgkins	57	54.3%
Timing of PET/CT	Initial staging	21	20%
	End-of-therapy	57	54.3%
	Suspected relapse	27	25.7%
Interpretation of the scan	only PET image	40	10.7%
	Fused (PET + CT) image	333	89.3%

Types of Pitfalls:

Total numbers of pitfalls detected were 373 sites. 71 sites are physiological pitfalls (19.1%). 128 sites were technical artifacts (34.3%). 156 sites were Therapy-related pitfalls (41.8%) and 18 sites were incidental benign conditions (4.8%) ***(Figure 1).***

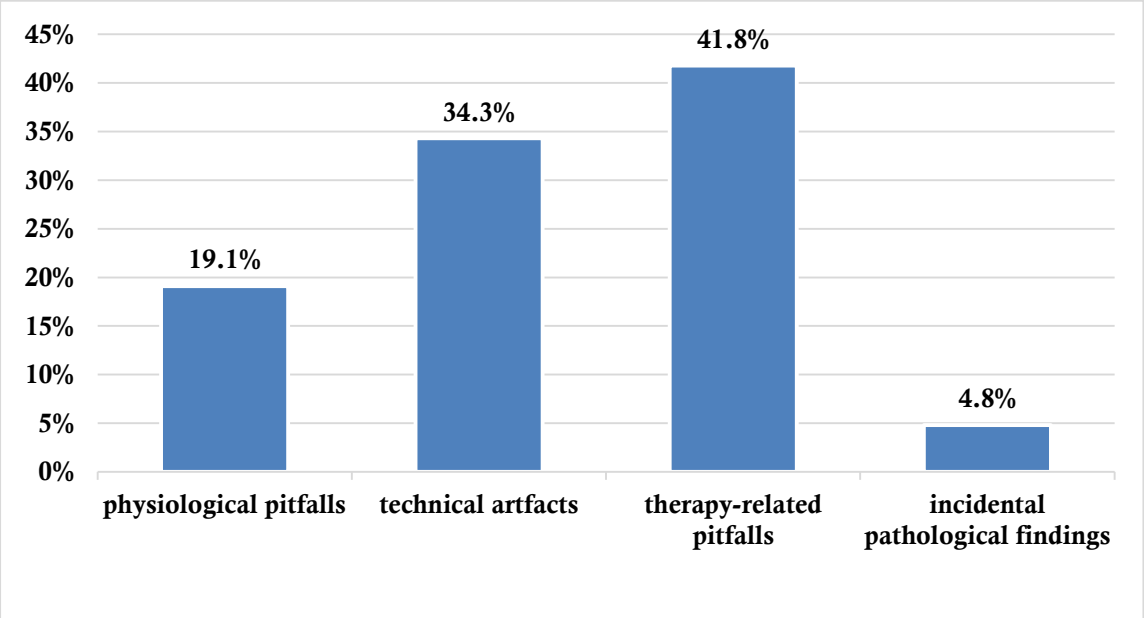

Figure 1: Detected Pitfalls in 373 sites of malignant lymphoma patients.

(1) Physiological pitfalls:

Total cases with physiological pitfalls were 71 sites. 36 sites had muscle uptake (50.7%). A total of 12 sites had uterine-related uptake pitfalls {(25.4%) (Menstrual-related uptake (16.9%), IUCD (2.8%) and both menses and IUCD (5.7%)}.12 sites had brown adipose tissue uptake (16.9%). 5 sites had unilateral vocal cord uptake (7%) ***(Table 2 and Fig 2).***

Table 2: Physiological Pitfalls in 70 sites in malignant lymphoma patients:

Variables		Frequency	
		Number	(%)
Muscle uptake		36	50.7%
Endometrial/ adnexal uptake (18) sites (25.4%)	**Endometrial/ adnexal uptake**	12	16.9%
	IUCD	2	2.8%
	Both	4	5.7%
Brown adipose tissue (BAT)		12	16.9%
Vocal cord (asymmetric) uptake		5	7%

IUCD: Intrauterine Contraceptive Device.

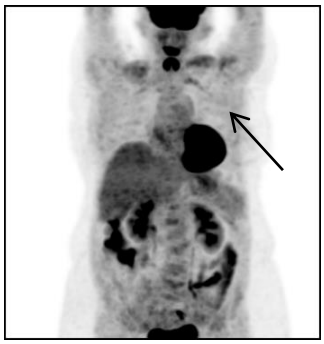

Fig (2): MIP FDG PET image shows physiologic muscle and vocal cord uptake (A) symmetrical bilateral FDG uptake over both shoulder girdle muscles uptake related to history of strenuous muscle activity; (B), intense symmetrical uptake is both hyper metabolic uptake in vocal cords due to the patient speech following injection.

(2) Technical pitfalls:

128 sites showed technical artifacts, as follow: 50 sites showed contrast-induced artifacts (39%), 41 sites showed head movement (32%), 36 sites showed metallic prosthesis/port-a-Cath (28.2%) and only one site showed truncation effect (0.8%) as seen in***(Table 3 and Fig 3)***.

Table 3: Technical artifact in 128 sites among 105 ML patients.

Variables		Number	%
Contrast-induced artifact		50	39%
Head movement		41	32%
Foreign body artifacts 36 sites (28.2%)	Metallic prosthesis	35	27.4 %
	Port-a-cath	1	0.8%
Patient positioning (Truncation effect)		1	0.8%

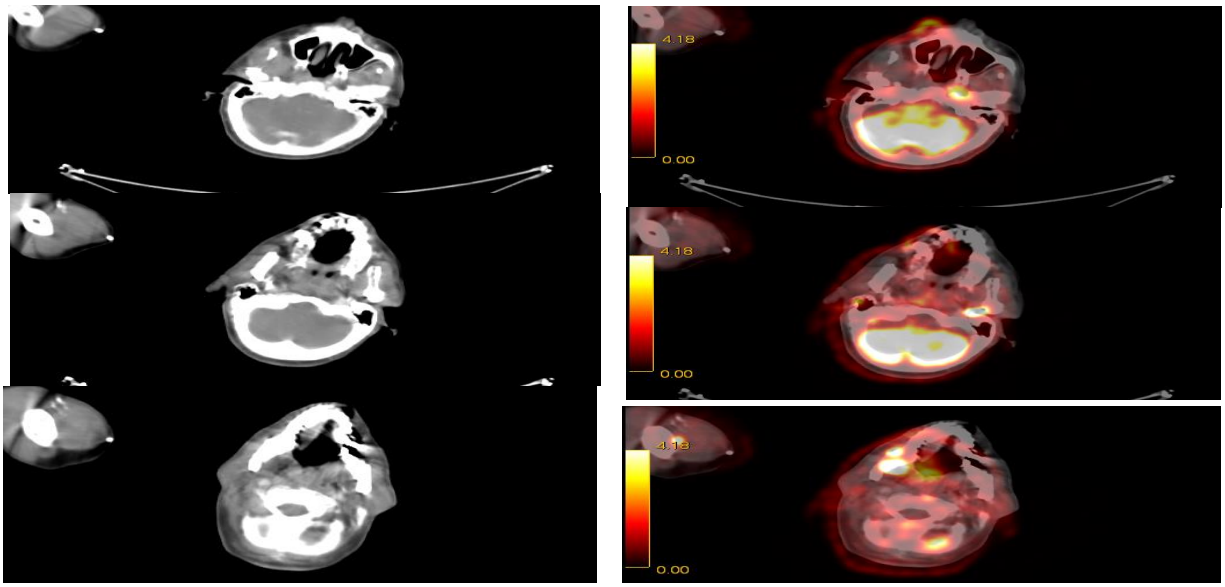

Fig 3: Both CT and fused image showed marked head movement during the study.

(3) Therapy-related pitfalls:

Post-therapy pitfalls were evident in 156 sites: (56 sites had enhanced gastric uptake (35.9%). 54 sites had splenic & BM uptake and 30 patients had enhanced salivary uptake (28.6%). While, 6 sites had diminished salivary uptake following radiation therapy (5.7%), 6 sites had thymic hyperplasia (3.9%) and 4 sites had early and late radiation effect (2.6 %) ***(Table 4 and Fig 4)***.

Table 4: Therapy-related Pitfalls among in 156 sites of malignant lymphoma.

Variables		Frequency	
		Number	**(%)**
Gastric uptake	Diffuse	50	32.1%
56 sites (35.9%)	Focal	6	3.8%
Splenic & BM uptake 54 sites (34.6%)	Splenic uptake only	1	0.6%
	BM uptake only	31	19.9%
	Both	22	14.1%
Salivary uptake	Early diffuse salivary uptake	30	19.2%
36 sites (23.1%)	Post R/TH diminished salivary uptake	6	3.9%
Thymic hyperplasia		6	3.9%
Radiation therapy effect	Early R/TH	1	0.6%
4 sites (2.6%)	Late R/TH	3	2%

Radiation therapy (R/TH). Bone marrow (BM).

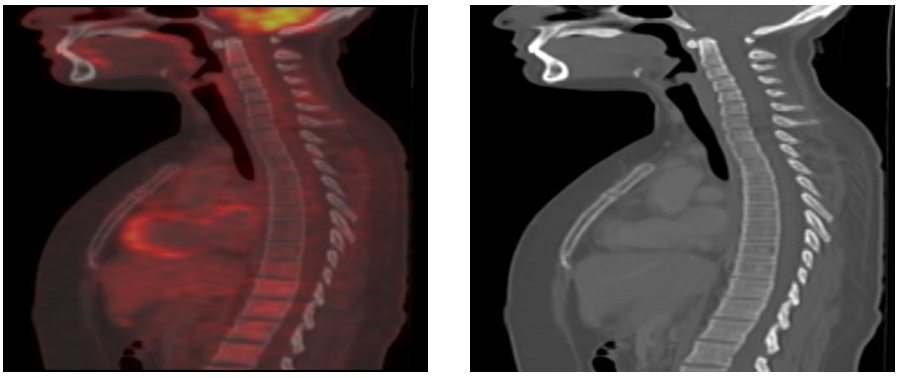

Fig 4: Sagittal CT and fused images revealed diffuse decrease in FDG uptake in upper dorsal region related to previous radiation therapy 7 months ago, while CT showed no pathological changes.

(4) Pathological benign conditions:

18 incidental pathological findings that represent potentials for imaging pitfalls were depicted in our study. 9 sites had incidental thyroid uptake (8.6%), (5 sites had focal uptake, 3 sites had nodular goiter and only one site had diffuse uptake). The average SUV max of thyroid lesions was (6.78 ± 4.06). Also, 8 patients had patchy inflammatory lung uptake (7.6%); with average SUV max of (5.04 ± 4.03). Only one patient had focal bone uptake attributed to fracture ***(Table 5 and figure 5)***.

Table 5: Benign Pathological Pitfalls in 18 sites in malignant lymphoma patients

Variables		Frequency		SUV $_{Max}$
		Number	(%)	
Thyroid uptake 9 sites (50%)	**Focal lesion**	5	27.8%	6.78 ± 4.06
	Nodular goiter	3	16.7%	
	Diffuse uptake	1	5.6%	
Lung uptake 8 sites (44.4%)	**Pulmonic patches**	3	16.7%	5.04 ± 4.03
	Consolidative changes (Infection)	5	27.8%	
Bone uptake (fractures)		1	5.6%	----------

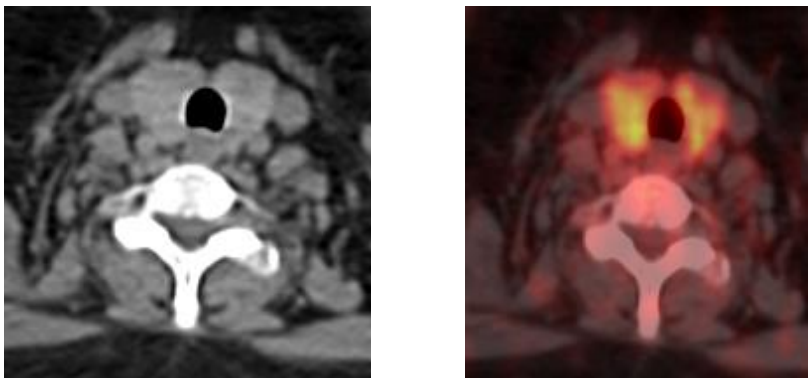

Fig 5: Both CT and fused PET/CT images revealed thyroid gland nodularity with faint increased tracer uptake related to possible nodular goiter.

DISCUSSIONS:

18F-FDG PET/CT has become a standard procedure for the evaluation of lymphomas. An understanding of the role of FDG PET/CT in the management of lymphomas and knowledge of its limitations is mandatory for the optimal utilization of this technique. The use of combined PET/CT imaging system creates distinctive artifacts that are not seen on dedicated PET-only systems. Some artifacts are related to the use of CT data rather than PET data for attenuation correction [(7)]. In the present retrospective study, we re-evaluated 105 adult patients with pathologically proven malignant lymphoma to estimate the prevalence of common pitfalls and artifacts in their PET/CT scans. The 105 malignant lymphoma patients were pathological type of lymphoma, into NHL (54.3% of patients), and HD (45.7% of patients). Proper interpretation of 18F-FDG PET/CT studies requires knowledge of the normal distribution of 18F-FDG uptake, as well as of the physiologic variants, benign lesions, and PET/CT-related artifacts. Knowing these potential causes of misinterpretation can increase accuracy in PET image interpretation, decrease the number of unnecessary follow-up studies or procedures, and improve patient management and treatment. The commonest pitfalls and artifacts in the present study are therapy-related artifacts; followed by technical artifacts, followed by physiological uptake sites and finally benign lesions. ***Whereas, Castellucci et al,*** that stated that the most frequent cause of non- tumoral FDG focal uptake in lymphoma patients was due to physiologic uptake and benign non-specific inflammation [(9)]. The difference in frequency of pitfalls in such studies is related to variable factors including age, number of patient and site of physiologic uptake included in different studies.

Physiological Pitfalls:

Sites of high physiological uptake such as the brain, myocardium, gastrointestinal tract, urinary tract, lymphoid tissue, brown adipose tissue, salivary glands, and thymus may obscure or mimic the presence of tumor deposits [(10, 11)].

Brown Adipose Tissue (BAT) with high18F-FDG uptake may complicate interpretation and quantification of PET images, especially in regions of possible lymph node metastases such as the axilla and the mediastinum.

Aukema et al., showed that ^{18}FFDG uptake in BAT was identified in 16% of their patients without drug intervention, while in the group of patients given 10 mg of diazepam protocol, only 4% showed BAT uptake. They therefore concluded that 18F-FDG uptake in BAT can be reduced by a single oral administration of diazepam combined with controlled room temperature in resting rooms [(12)]. Regarding our study, 12 out of 105 patients (11.4%) showed enhanced brown fat FDG uptake which was evident in cervical, supra clavicular and para-spinal regions. We didn't use any drug preparation; however, the combined PET/CT is now helpful to solve this problem. On the other hand; ***Park et al.,*** stated that the prevalence of BAT in their study was only 1.07%, with higher incidence in younger age and cold outdoor temperature. The most frequent location of BAT was the supraclavicular area and ventral neck area. They argued that the low prevalence of BAT in their study might be related to conditions like ambient temperature [(13)]. Muscle uptake of 18F-FDG may obscure sites of pathologic uptake. Therefore, patients should avoid heavy physical exertion for at least 24 hours, should rest comfortably during the uptake phase. Instructions may be given to patients to avoid excessive exercise during the 48 hours prior to injection. Furthermore, technologists should report any excessive physical activity by the patient during the uptake phase which would in turn help guide the physician while reporting [(14)]. In a study conducted by ***Jakcson, et al.*** a total of 146 of 1,164 patients (12.5%) had excessively increased muscle uptake detected on the PET scan that corresponded to the technologists' notes of muscle activity during the uptake phase or before 18F-FDG injection. Encountered patterns of muscle uptake due to muscle activity included uptake in neck, secondary to neck strain from being on a stretcher; masseter, secondary to chewing gum; vocal cords, secondary to speaking; chest wall, secondary to labored breathing; forearms and hands, secondary to reading; and lower extremities, secondary to nervous tapping of the feet [(15)].

Regarding the present study; 36 out of 105 sites (34.3%) were reported in the present study to show enhanced muscle FDG uptake related to heavy exercise. As patients were not aware of importance to stop such exercise in last 24 hrs before PET/CT examination.

The FDG uptake of normal laryngeal tissue is symmetric and low, while benign lesions typically have only slight increases in FDG uptake.

Asymmetric, physiologic FDG uptake is noted in the contralateral vocal cord of patients with a unilateral vocal cord paralysis. The FDG uptake of the non-paralyzed vocal cord is increased multiple-fold, placing it well within the range of malignancy. Use of unique, combined PET-CT imaging localized the high FDG uptake to the non-paralyzed vocal cord, and laryngoscopy is the standard tool to confirm or exclude evidence of malignancy in the vocal cord. This potential pitfall in the interpretation of FDG-PET imaging can be resolved with the use of combined PET-CT imaging and clinical correlation. Asymmetric vocal cord uptake suggests the possibility of disease such as malignancy, post therapy change, or unilateral vocal cord paralysis [(16)]. In the present study; 5 out of 105 patients (4.8 %) was reported to show enhanced asymmetric vocal cord uptake for the same reasons related to unilateral vocal cord paralysis related to large mediastinal lymph node compressing Vagus nerve. This was improved during follow up PET/CT in 3 patients attending after treatment with chemotherapy and marked reduction in nodal lesions. Before the age, of puberty no 18F-FDG uptake is detected in the ovaries, but inflammatory processes, physiologic corpus luteum cysts and some other ovarian cysts may cause mild increased FDG uptake [(17)]. In our study, 12 out of 40 female patients (30%) showed endometrial/adnexal mild degree of FDG uptake that was attributed to mid menstrual cycle in their clinical. 6 patients showed FDG uptake around IUCD; 4 female patients showed menstrual-related endometrial/adnexal FDG uptake as well as FDG uptake around IUCD.

Also, ***Abu Zeid et al,*** showed that diffuse FDG ovarian uptake during mid-menstrual cycle. Therefore, combined PET/CT allows precise anatomic localization of 18FFDG uptake to ovarian structures, thereby improving differentiation of normal physiologic uptake from disease [(7)].

Technical related artifacts: The most commonly seen artifacts are related to the use of CT data rather than PET data for attenuation correction. Metallic objects may cause artificially increased activity, representing a pitfall.

The high CT attenuation values cause falsely high PET attenuation coefficients, leading to overestimation of the PET activity corresponding to the metallic objects on the attenuation-corrected images [(11)].

In our study, metallic artifacts was detected in 35 out of 105 sites (33.3%) Most of them are attributed to dental implants; 1 site was found to be related to port-a-cath. Such metallic artifacts can easily detect in CT part of study and not seen in PET/Images. ***Also, Nawwar, et al., reported*** that CT-related artifacts, metallic artifacts were found in 41 sites, the majority of which were due to earrings and dental metal work, followed by port-a-cath and external metallic objects; only one patient with aortic metal clips [(8)]. Intravenous contrast material is typically seen in the axillary region just proximal to the intravenous catheter. Concerning oral contrast, the risk of artifacts may be lower with negative contrast agents, such as water and with iodinated oral contrast, possibly because iodinated contrast agents typically are used in diluted form and have a lower density than barium contrast agents. Oral contrast agents should be given only with non- caloric liquids if they are administered before the 18F-FDG PET scan [(7)].

The present study depicted 50 out of 105 (47.6%) patients with contrast-induced technical artifacts. However, such pitfall is mandatory to detect small lesion in lymph nodes especially in abdominal and pelvic region. Patient movement can interfere with the image acquisition, PET and CT image registration, and the CT derived PET attenuation correction which varied from head movements or the patient just not being centralized on the table [(16)]. In our study; head movement was detected in 41 out of 105 sites (39%) most of them related to head movements.

Also, ***Burrell and Van den Abbeele.*** Reported many patients with movement artifacts [(21)].

Therapy Related Pitfalls: Bone marrow hyperplasia secondary to chemotherapy with or without cytokines, such as granulocyte colony-stimulating factor, may lead to increased FDG uptake up to 3 weeks after the last dose of cytokines. Similar effects can be seen in the spleen. ***Hanaoka, et al.*** conducted a study to clarify the change in the fluorodeoxyglucose (FDG) uptake by the bone marrow; a total of 127 patients with confirmed non-Hodgkin's lymphoma who underwent FDG PET within 60 days from the last administration of G-CSF were reviewed.

Physiological bone marrow uptake of the spine was determined in patients with lymphoma, bone marrow SUV decreased over time and reached a plateau at about 14 days after G-CSF administration, SUV declined to the 'physiological range', at about 7 days. The study concluded for a PET/CT study, an interval of 10 days after G-CSF administration is recommended to minimize the influence of G-CSF on the bone marrow when evaluating treatment response in patients with non-Hodgkin's lymphoma [(18)]. In our study we picked up a total of 54 patients (51.4%) with splenic & BM uptake, correlation with the clinical history revealed that 22 cases were concurrently receiving G-CSF following chemotherapy which was missed in clinical history, whereas majority of patients had bone marrow hyperplasia related to early imaging within 2 weeks after chemotherapy. Also, in our study, we depicted 4 patients with altered FDG uptake that is attributed to radiation therapy effect (one patient showed enhanced FDG uptake as an early response to R/TH, the other 3 sites showed diminished uptake that is attributed to late effect of R/TH after 6-8 months of radiation therapy. In this study, we reported 36 patients with enhanced salivary uptake; 30 sites of them were scanned following chemotherapy, the other 6 patients were scanned more than 6 months following local radiation therapy. Also, ***Nakamoto et al***., reported mild to moderate parotid gland uptake in 51% of patients and intense parotid gland uptake in 14%. They stated that the uptake in the submandibular and sublingual glands was variable, with positive rates of 53% and 72%, respectively. Diffuse increased uptake in the salivary glands may also be seen after chemotherapy or radiation therapy [(16)]. Similarly, ***Nawwar, et al.,***found enhanced early uptake in the salivary glands in 9.9% of their patients which is related to post chemotherapy changes which is seen as bilateral and symmetrical increase FDG uptake [(8)]. Diffuse 18F-FDG uptake in the thymic region. Usually represents age-related physiologic activation. In general, the observed FDG tracer activity decreases with age, corresponding to normal involution change of the thymus. A similar pattern, termed “thymic rebound”, can be observed 4 to 6 months after completion of chemotherapy. The inverse-V pattern of FDG uptake is typical of the thymus, but correlation or co registration with a chest CT can be used to confirm that the uptake is in the thymus.

Therefore, the level of the thymic tracer activity is deemed "normal physiologic" in absence of abnormal morphological features on CT [19]. We depicted in this study 6 patients with enhanced FDG uptake at the anterior mediastinum that was proved by CT correlation to be attributed to thymic hyperplasia; all of the 6 patients had PET/CT following Chemotherapy and their age were less than 35 years. Similar pattern reported by ***Nawwar, et al***., with diffuse thymic FDG uptake is one of the main concerns especially in lymphoma following chemotherapy, which was found in 12 sites (4.7%), representing a major mediastinal pitfall especially in pediatric group.

Benign conditions representing potential pitfalls: Benign conditions with increased glycolysis, such as infection, inflammation, and granulomatous disease, may also lead to increased FDG uptake, and be mistaken for lymphomatous deposits. Inflammatory changes secondary to surgery, radiotherapy, and chemotherapy may also lead to false-positive results. Pattern of lung uptake differed from bilateral patchy uptake to basal patchy uptake with inflammatory changes in the CT part of study. Pneumonia may manifest with marked focal increased uptake in the lung, usually resolving after antibiotic therapy [20].

In our study; we picked up 8 out of 105 sites (7.6%) with patchy lung uptake; 5 sites of them had consolidative changes suggestive of infection.

Whereas 3 out of the 8 sites had pulmonic patches/parenchymal infiltrates with average SUV max of (5.04 ± 4.03). Follow up of these patients with diagnostic CT and or PET/CT revealed resolution of inflammatory changes in 5 patients of them. Similar findings were reported by ***Mehesen and Fathy.*** with pulmonary inflammation or infection in 18 patients, however during follow up PET/CT of those cases showed disappearance of uptake was seen in 9 patients of them. Pattern of uptake differed from bilateral patchy uptake to basal patchy uptake with inflammatory changes in the CT part of study [22].

Patients with focal uptake in the region of the thyroid should be further evaluated because of a higher risk of the finding being associated with malignancy. Uptake could also be diffuse as in thyroiditis or Graves' disease [21].

In our study; we picked up 9 out of 105 sites (8.6%) with thyroid FDG uptake; 5 of them showed focal thyroidal FDG uptake, 3 of them showed nodular pattern of FDG uptake, one of them showed diffuse thyroid uptake. No available pathology was evident in clinical sheet of patients.

CONCLUSIONS: Proper clinical history with data from referring physician are needed for proper interpretation of PET/CT in order to have good experience with different pitfalls and artifacts for good diagnosis in malignant lymphoma.

REFERENCES:

1. ***Ibrahim AS,KhaledHM, Mikhail NH, et al.*** cancer incidence in Egypt: results of the national population-based cancer registry program; Published 21 September; 2014.

2. ***Ambinder RF, Browning PJ, Lorenzana I, et al.*** Epstein-Barr virus and childhood Hodgkin's disease in Honduras and the United States. Blood. Jan 15; 81(2):462-7; 1993.

3. ***Filipovich AH, Mathur A, Kamat D, et al.*** Primary immunodeficiency: genetic risk factors for lymphoma. Cancer Res. Oct 1; 52(19 Suppl):5465s-7s; 1992.

4. ***Mack TM, Cozen W, Shibata DK, et al.*** Concordance for Hodgkin's disease in identical twins suggesting genetic susceptibility to the young-adult form of the disease. N. Engl. J. Med. Feb 16; 332(7):413-8; 1995.

5. ***Cogliano VJ, Baan R, Straif K, et al.*** Preventable Exposures Associated With Human Cancers. JNCI.103(24):1827-39; 2011.

6. ***Lukes RJ and Butler JJ:*** The pathology and nomenclature of Hodgkin's disease. Cancer Res: 26:1063-1083; 1966.

7. ***Abouzied MM, Crawford ES, Nabi HA.*** 18F-FDG imaging: pitfalls and artifacts. Journal of nuclear medicine technology. 33(3):145-55; 2005.

8. ***Nawwar A, Abou Gabal M, Tawakol A, et al,.*** Tumor primary and possible PET falls in paediatric PET/CT. Annual congress of European Association of Nuclear Medicine (Abstract). 21 – 25 October; 2017.

9. ***Castellucci P, Nanni C, Farsad M, et al.*** Potential pitfalls of 18F-FDG PET in a large series of patients treated for malignant lymphoma: Prevalence and scan interpretation. Nucl. Med. Commun. 26:689–94; 2005.

10. ***Delbeke D, Coleman RE, Guiberteau MJ, et al.*** Procedure guideline for tumor imaging with 18 F-FDG PET/CT 1.0. J. Nucl. Med. 47:885–95; 2006.

11. ***Kumar R, Halanaik D, Malhotra A.*** Clinical applications of positron emission tomography-computed tomography in oncology. Indian J. Cancer. 47:100–19; 2010.

12. ***Aukema TS, Vogel WV, et al.*** Prevention of brown adipose tissue activation in 18F-FDG PET/CT of breast cancer patients receiving Neoadjuvant systemic therapy. J. Nucl. Med. Technol. 38(1):24-7; 2010.

13. ***Park JY, Lim JS, Park EY, et al.*** The Prevalence and Characteristics of Brown Adipose Tissue in an (18) F-FDG PET Study of Koreans. Nuclear medicine and molecular imaging. 44(3):207-12; 2010.

14. Hanaoka K; Department of Radiology, Kinki University Hospital, Osaka-Sayama, Japan.Aug; 32(8):678-83; 2011.

15. ***Jackson RS, Schlarman TC, Hubble WL, et al.*** Prevalence and patterns of physiologic muscle uptake detected with whole-body 18F-FDG PET. J. Nucl. Med. Technol. 34(1):29-33; 2006.

16. ***Nakamoto Y, Tatsumi M, Hammoud D, et al,.*** Normal FDG distribution patterns in the head and neck: PET/CT evaluation. Radiology. 234(3):879-85; 2005.

17. ***Lerman H and Metser U.*** Normal and abnormal 18F-FDG endometrial and ovarian uptake in pre- and postmenopausal patients: assessment by PET/CT. Journal of nuclear medicine: official publication, Society of Nuclear Medicine.45(2):266-71; 2004.

18. ***Kazama T and Swanston N.*** Effect of colony stimulating factor and conventional- or high-dose radiotherapy on FDG uptake in bone marrow. Eur. J. Nucl. Med. Mol. Imaging. 32(12):1406-11; 2005.

19. ***Brink I, Reinhardt MJ, Hoegerle S, et al,.*** Increased metabolic activity in the thymus gland studied with 18F-FDG PET: age dependency and frequency after chemotherapy. Journal of nuclear medicine: official publication, Society of Nuclear Medicine. 42 (4):591-5; 2001.

20. ***Kapucu LO, Meltzer CC, Townsend DW, et al,.*** Fluorine-18-fluorodeoxyglucose uptake in pneumonia. Journal of nuclear medicine: official publication, Society of Nuclear Medicine. 39(7):1267-9; 1998.

21. ***Burrell SC and Van den Abbeele AD.*** 2-Deoxy-2-[F-18] fluoro-D-glucose-positron emission tomography of the head and neck: an atlas of normal uptake and variants. Molecular imaging and biology: MIB: the official publication of the Academy of Molecular Imaging. 7(3):244-56; 2005.

22. ***Mehesen, M and Fathy, H.*** Impact of 18F-FDG PET/CT Dual Time Point Imaging in Lymphoma Patients with Lung Lesions. Egyptian J. Nucl. Med. Vol. 18, No. 1:52-67; 2019.