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PET/CT vs CECT in assessment of therapeutic response in lymphoma

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Abstract

Background: Lymphoma incorporates histologically variable cancers derived from the immune system cells. The distinctive feature of lymphoma is the rapid increase in size and number of lymph nodes and/or secondary lymphoid tissues.

The aim of the work is to evaluate the accuracy of PET/CT vs CECT in the assessment of response to therapy in lymphoma patients: both early and late therapeutic response assessment.

This retrospective study was conducted on 80 patients with different types of lymphoma recruited and enrolled from a university hospital. All 80 patients underwent pre-treatment, during the course of chemotherapy and at the end of planned treatment contrast-enhanced CT (CECT) and PET-CT. Interpretation of the CECT and the fusion images PET/CT each was done separately and comparison of the results was achieved.

Results: PET/CT and contrast-enhanced computed tomography were concurrent in results in 55% of cases during treatment and 75% at the end of treatment with CT sensitivity of 61.1%, specificity of 92.2%, and accuracy of 76.2% during treatment in comparison to 100% sensitivity and specificity of PET/CT. Sensitivity of CT at end of treatment was 57.5%, specificity 86.7%, and accuracy 71.6% as compared to 100% sensitivity and specificity of PET/CT.

Conclusion: PET/CT using 2-deoxy-2-[18F] fluoro-D-glucose is considered one of the best oncologic imaging modalities at the time being with valuable applications in lymphoma. It is very efficient with least possible pitfalls and false results compared to either of its components alone and to side by side reading of separately acquired PET and CT. PET/CT can detect both anatomical information as well as metabolical information providing more data and thus giving more accurate results than CECT. It is becoming a standard modality for lymphoma providing a new vision to management and treatment plan.

Keywords: Therapeutic response, Lymphoma, PET/CT, CECT

Background

Lymphoma incorporates over 50 biologically and histologically different types of lymphoid malignancies. Lymphoma is classified into Hodgkin lymphoma (HL) and non-Hodgkin lymphoma (NHL) [1].

The metabolic response to therapy can be detected in the interim PET after a few cycles of chemotherapy and in end-of-treatment (EOT) PET. The 18F-fluorodeoxyglucose uptake markedly decreases with reduction in the SUV when the tumoral cells respond to therapy [2].

PET/CT with [18F]FDG is considered one of the most widely used imaging techniques to evaluate both early and late treatment response during as well as after therapy in patients suffering from lymphomas [3].

PET/CT using (18F) FDG is considered one of the functional imaging techniques used to assess the glucose metabolism in vivo; its use has been widely increased in the evaluation of oncology patients being highly sensitive in assessment of malignancy as PET/CT can detect malignancy prior to morphological changes [4].

In daily practice, PET/CT is used in patients suffering from both HL and NHL to evaluate the sensitivity to

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chemotherapy in the "interim" PET/CT and to predict the clinical outcome post-therapy [5].

At the end of treatment, residual masses are commonly detected on CT scan, but PET/CT can differentiate between viable pathological cells and nonviable fibrotic scar tissue with high accuracy [6].

The response to therapy is assessed according to the metabolic activity of target lesions using a 5-point scale (5-PS) known as the DC [7].

Methods

Subjects

This retrospective study was conducted on 80 patients with different types of lymphoma recruited and enrolled from a university hospital. Patients underwent pre-treatment PET-CT, during the course of chemotherapy and at the end of planned treatment or for relapsed /refractory disease prior to new treatment according to the protocol at our hospital (Fig. 1).

Ethics approval and consent to participate

Not applicable. This was a retrospective study. We collected the data from the records of the patients and the institutional review board waived the requirement for informed patient consent.

The inclusion criteria are as follows:

1. Patients with pathologically proved lymphoma (different types)
2. No age or sex predilection

The exclusion criteria are as follows:

1. History of atopic disorders
2. Patients with renal function impairment (with serum creatinine > 2 mg/dl)

Technique of PET/CT

Specific information required for optimal interpretation of CECT and FDG PET/CT images, such as clinical history; results of previous imaging studies; and history of surgery, chemotherapy, or radiation therapy, were obtained.

A thorough explanation of the procedure was given to the patient and consent was obtained.

Patients underwent pre-treatment PET-CT, during the course of chemotherapy and at the end of planned treatment or for relapsed/refractory disease prior new treatment according to the protocol at our hospital.

The study was conducted in PET/CT unit at Ain Shams University hospitals on GE PET-CT Discovery IQ 5 Rings machine with Dual Acquisition Channels, 50-slice equivalent CT speed with IQE 1.75 pitch booster, 20 mm CT coverage, and Q-clear attenuation correction.

Patients fasted for at least 6 h before the examination but were asked to drink water to maintain good hydration if anesthesia or sedation was not indicated and blood glucose levels were less than 200 mg/dL. A dose of 6–7 MBq/kg (0.1 mCi/kg, minimum 3 mCi) FDG was injected intravenously. The patients rested in a quiet room. After the 45–60-min uptake period, the patients were taken for the PET-CT study. CECT from the skull to the mid-thigh was performed by using a 16-detector row CT scanner. Intravenous bolus injection of a non-ionic iodinated contrast material at a dose of 2–3 mL/kg of body weight was performed just before initiation of scanning. Scanning protocols with 120 kVp and effective tube current that varied from 120 to 160 mAs were used.

After CT acquisition, PET acquisition of the same axial range began with the patient in the same position on the table for 2–3 min per bed position with bed overlapping slice acquisition. PET data were acquired by

Fig. 1 Flowchart of the research methodology

Table 1 Lugano Criteria for Response Assessment on CT and FDG-PET/CT [8]

Modality	Clinical Application	Complete Response	Partial Remission/ Partial Response	Stable Disease/ No Response	Progressive Disease
CT	All lymphoma (if CT is performed for tumor size measurement); primary assessment modality for non–FDG-avid lymphoma	Complete radiologic response: Nodal sites reduced to ≤1.5 cm in LDi Complete disappearance of radiologic evidence of disease	Partial remission: For multiple lesions, ≥50% decrease in SPD of up to six target measurable nodes and extranodal sites If only a single lesion is present, ≥50% decrease in the PPD	Stable disease: <50% decrease from baseline in SPD of up to six dominant, measurable nodes and extranodal sites; no criteria for progressive disease are met	May be based on a single dominant lesion; progressive disease is assigned with at least one of the following: 1. New or increased adenopathy; an individual node must be abnormal with: (a) LDi > 1.5 cm AND (b) PPD increase by ≥ 50% from nadir AND (c) LDi or SDi increase from nadir; the increase in LDi or SDi from nadir (the smallest recorded measurement) must be > 0.5 cm for lesions ≤ 2 cm and > 1.0 cm for lesions > 2 cm 2. Splenic volume increase: (a) With prior splenomegaly: increase in length by > 50% of its prior increase beyond baseline; for example, splenic length increases from 15 cm (2 cm above baseline splenomegaly of 13 cm) to >16 cm (>3 cm above baseline) (b) Without prior splenomegaly: length increase by at least 2 cm (c) New or recurrent splenomegaly 3. New or larger nonmeasured lesions 4. Recurrent previously resolved lesions 5. New extranodal lesion > 1 cm in any axis (new lesions < 1 cm in any axis are included if these are "unequivocally attributable" to lymphoma) 6. A new node > 1.5 cm in any axis
FDG PET/ CT	FDG-avid lymphoma (including Hodgkin lymphoma and diffuse large B-cell lymphoma)	Complete metabolic response: Score of 1, 2, 3 in nodal or extranodal sites with or without a residual mass	Partial metabolic response: Score of 4 or 5 with reduced uptake compared with baseline and residual mass(es) of any size	No metabolic response: Score of 4 or 5 with no obvious change in FDG uptake	Score 4 or 5 in any lesion with an increase in intensity of uptake from baseline and/or New FDG-avid foci consistent with lymphoma

Note: Data from Cheson et al. [9]

Table 2 The five-point scale used to assess treatment response by FDG PET/CT

Score	Description
I	No uptake
2	Uptake ≤ mediastinum
3	Uptake > mediastinum but ≤ liver
4	Uptake moderately increased above liver at any site
5	Markedly increased uptake above liver at any site
NE	Not evaluable
X	Any areas of uptake not likely to be related to lymphoma

Note: Data from Cheson et al.[10]

using a matrix of 128 × 128 pixels. CT-based attenuation correction of the emission images was used. After PET data acquisition was completed, the reconstructed attenuation-corrected PET images, CT images, and fused images of matching pairs of PET and CT images were available for review in axial, coronal, and sagittal planes, as well as in maximum intensity projections and in three-dimensional cine mode.

Image analysis
Interpretation of the CECT (contrast-enhanced CT) and the fusion images PET/CT each was done by two radiologists with 5 and 10 years' experience and consensus decision was used for the study.

CECT assessment
A lymph node was considered suspicious if it lost its fatty central hilum, became more rounded than ovoid, and attained peripheral rather than central vascularity with a maximum diameter greater than 1.5 cm. An enlarged spleen was considered one sign of splenic involvement in lymphoma with the upper cut off value for its vertical length of 13 cm. This together with focal splenic lesions or military infiltration was suggestive of splenic involvement. Four categories for CT have been outlined: (a) complete radiologic response, all nodes less than or equal to 1.5 cm in longest diameter, and disappearance of all CT findings of lymphoma; (b) partial remission, 50% or greater decrease in disease burden; (c) stable disease, less than 50% decrease in disease burden; and (d) progressive disease, new or increased adenopathy or new extra nodal lymphoma [8].

PET assessment
Any focus of elevated FDG metabolism in comparison with liver and mediastinum, not located in areas of normal FDG uptake, was considered to be abnormal. Visual inspection was used routinely for assessment and SUV is used in assessing questionable lesions. The areas of FDG uptake were localized anatomically on CT scans. In our study, we evaluate the response

Table 3 Demographic data distribution of the study group

	Number	Percent
Sex		
Female	12	60.0
Male	8	40.0
Age (years)		
≤ 35 years	10	50.0
> 35 years	10	50.0
Range [mean ± SD]	18–64 [35.35 ± 14.06]	

Table 4 Lymphoma subtypes of the enrolled study group

	Number	Percent
Type		
HL	12	60.0
NHL	8	40.0
Subtype		
Anaplastic	1	5.0
B cell	5	25.0
Large B cell	7	35.0
Mixed cellular	3	15.0
NLPHL	1	5.0
Nodular sclerosis	3	15.0

according to the new Lugano criteria for using CT and FDG PET/CT (Table 1).

The five-point scale (Table 2) is now applied to both interim and end-of-treatment FDG PET/CT response assessment. Four categories of response have been outlined as follows: (a) complete metabolic response—score of 1, 2, or 3; (b) partial metabolic response—score of 4 or 5 with reduced FDG uptake; (c) no metabolic response—score of 4 or 5 without significant change in FDG uptake; and (d) progressive metabolic disease—score of 4 or 5 with increased FDG uptake or with new lesions [8]. Comparison between fused PET-CT images findings and the contrast-enhanced CT study findings was done. The results were tabulated and statistically analyzed.

Data management and analysis
Statistical analysis
Recorded data were analyzed using the statistical package for social sciences, version 20.0 (SPSS Inc., Chicago, IL, USA). Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage.

The following tests were done:

Table 5 Treatment assessment distribution of the study group

	Number	Percent
CT		
Complete regression	3	15.0
Progression disease	2	10.0
Partial regression	15	75.0
Stationary disease	0	0.0
PET		
Complete regression	12	60.0
Progression disease	2	10.0
Partial regression	6	30.0
Stationary disease	0	0.0

Table 6 Relation between treatment assessment at CT and treatment assessment at PET-CT of the study group

Treatment assessment PET	Treatment assessment at CT						Total		Chi-square test	
	Complete regression		Progression disease		Partial regression					
	No.	%	No.	%	No.	%	No.	%	χ^2	P value
Complete regression	3	15.0	0	0.0	9	45.0	12	60.0	22.582	< 0.001**
Progression disease	0	0.0	2	10.0	0	0.0	2	10.0		
Partial regression	0	0.0	0	0.0	6	30.0	6	30.0		
Stationary disease	0	0.0	0	0.0	0	0.0	0	0.0		
Total	3	15.0	2	10.0	15	75.0	20	100.0		

χ^2, Chi-square test; **P value < 0.001 HS

1. Chi-square (χ^2) test of significance was used in order to compare proportions between qualitative parameters.
2. Pearson's correlation coefficient (r) test was used to assess the degree of association between two sets of variables
3. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So the P value was considered significant as follows:
   (a) Probability (P value)
   (b) P value ≤ 0.05 was considered significant.
   (c) P value ≤ 0.001 was considered highly significant.
   (d) P value > 0.05 was considered insignificant.

Results

A total of 80 patients with variable ages and different stages of different types of lymphoma were enrolled during the study period.

There were 32 male cases 40% and 48 female cases 60%. The age ranged from 18 to 64 years with mean 35.35 ± 14.06 (Table 3). Sixty percent of our cases were HL and 40% were NHL (Table 4).

All 80 patients underwent pre-treatment, during the course of chemotherapy and at the end of planned treatment CECT and PET-CT.
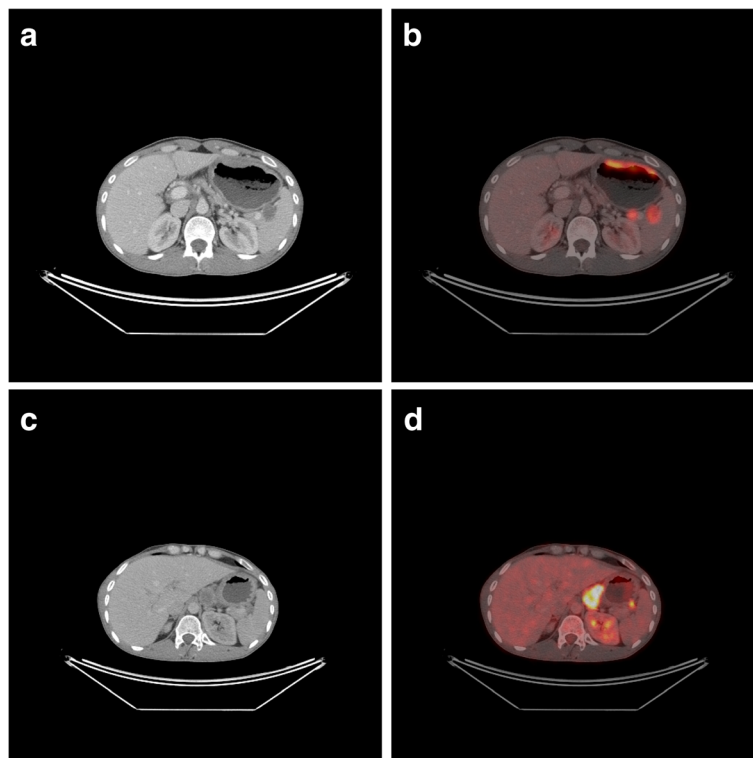
Fig. 2 A 29-year-old male, known case of gastric antrum and body B cell lymphoma, received CTH, the last session 2 weeks ago with irrelevant surgical history. **a**, **b** His initial PET/CT compared to his interment study revealed splenic hilar lymph node measuring 16 × 19 mm with SUV 9.6. **c**, **d** His interment study revealed no size change compared to the previous study yet reduced SUV max to be 8.9. This case was stationary by CT while regressive by PET

In first follow-up during the course of chemotherapy, out of the 80 cases, 18F-FDG PET/CT and CECT were concurrent in results in 44 out of the 80 cases (55%) and discordant in the other cases (45% *n* = 36) detailed as follows: CECT detected complete regression in 12 cases (15%), partial regression in 60 cases (75%), stationary course in 0 cases (0%), and progression in 8 cases (10%), while 18F-FDG PET/CT detected complete regression in 48 cases (60%), partial regression in 24 cases (30%), stationary course in 0 case (0%), and progression in 8 case (10%) (Tables 5 and 6). In one of these cases, the initial PET/CT compared to the interment study revealed stationary course as regards the size of the splenic hilar lymph yet with reduced SUV max. The course of the disease was stationary by CT while regressive by PET (Fig. 2). A residual mass was present in one of the cases on contrast-enhanced CT [partial response] without any uptake on PET (complete response) (Fig. 3). Thirty-six cases showed partial regression by CT and total regression by PET (Figs. 4 and 5).

At end of treatment assessment, CECT detected complete regression in 20 cases (25%), partial regression in 16 cases (20%), stationary course in 20 cases (25%), and relapse in 24 cases (30%), while 18F-FDG PET/CT detected complete regression in 36 cases (45%), partial regression in 12 cases (15%), stationary course in 4 cases (5%), and disease relapse in 28 cases (35%). There were statistically significant results in the follow-up of 6

months after the end of chemotherapy 18F-FDG PET/CT study (*P* value = 0.001). 18F-FDG PET/CT proved higher sensitivity and specificity over CECT in our study (Tables 7 and 8). In one of the cases, interim PET-CT showed right paratracheal enlarged lymph node on CT with no change in size, while PET CT images at end of therapy showed newly developed metabolic activity in it. The patient was categorized as stationary disease on CT and progressive disease on PET/CT (Fig. 6).

Discussion

Lymphoma consists of a heterogeneous group of diseases; marked improvement has been made in diagnosis and treatment. Imaging is important both for staging and assessment of response to therapy. Staging systems have been modified and specific criteria have been developed for assessment of response to therapy with both computed tomography (CT) and fluorine-18 fluorodeoxyglucose positron emission tomography (PET)/CT [8].

There are several common pitfalls in the diagnosis of lymphoma using PET alone. One of them is that gastric and cerebral lymphoma lesions are sometimes difficult to characterize on PET images due to physiologic gastric and cortical accumulation of FDG. Also, physiologic colonic uptake might be mistaken for lymphomatous infiltration. Another pitfall is that small-volume lesions might be undetectable on both pre- and post-therapy PET scans especially when there is high background activity
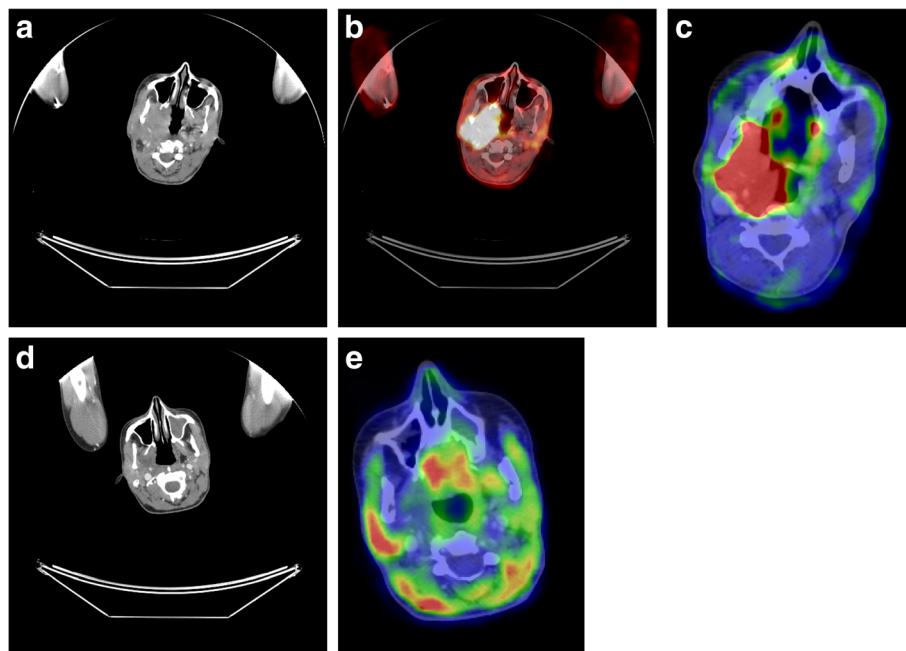
Fig. 3 A 25-year-old patient with large B cell lymphoma. **a, b** His initial study revealed a large ill-defined hypermetabolic right para-pharyngeal soft tissue mass lesion noted to be measuring about 5.7 × 7 × 7.5 cm achieving SUV max ~ 11.1. **c, d** His interment study revealed regressive course as regards the size of the previously reported soft tissue mass lesion roughly measuring about 2.5 × 2.5 × 5 cm; the mass is non-FDG avid with total metabolic response. This case showed partial regression by CT and total regression by PET/CT
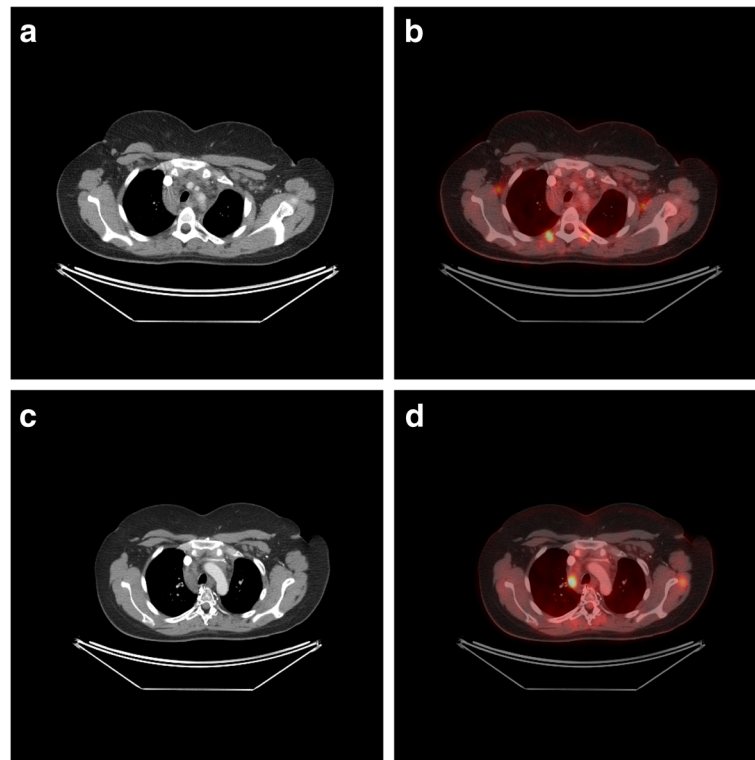
Fig. 4 A 34-year-old female patient known NHL. Interim PET-CT images (**a**, **b**) show subcentemetric non-metabolically active lymph node (arrows). PET CT images at end of therapy (**c**, **d**) showed no appreciable size change but with 18-FDG avid uptake. The patient was categorized as complete regression on CT and progressive on PET/CT

surrounding the lesions. Accurate correlation with anatomical CT findings is mandatory in avoiding such pitfalls; thus, integrated PET/CT is especially helpful [10].

Many reports in literature have assessed the role of PET/CT for evaluation of therapeutic response of lymphoma.

In our study, we evaluated both PET/CT and CECT for their role in assessment of response during the course and end of treatment in lymphoma patients.

The imaging evaluation and follow-up of lymphoma patients in the past depended only on CECT findings. However, CECT has relatively low sensitivity in determining lymphomatous involvement of average-sized lymph nodes, bone marrow, spleen, and extranodal tissues. The presence of residual lymph node mass was a frequently encountered diagnostic dilemma as it was difficult to differentiate between post-treatment fibrosis and residual viable tumorous tissue by CECT [11].

In our study, PET/CT was able to add clinically significant information not obtained by CT. On a regional-based survey of patients, PET/CT showed significantly better results than CECT in accurately identifying lymph node groups as positive or negative for lymphomatous involvement. PET/CT was also capable of detecting more extranodal sites of the

disease than CECT. PET/CT can assess therapeutic response more precisely than CECT.

18F-FDG PET/CT does not depend only on nodal size to determine the presence or absence of malignancy (anatomical evaluation), assessment of intra-nodal activity plays a very important role (metabolic evaluation). Average-sized lymph nodes might contain tumoral tissue on 18F-FDG PET/CT images, and enlarged lymph nodes can be reactional in nature. Hence, for this reason, PET proved to be more sensitive and specific than CT for detection of sites of lymphomatous infiltration [12].

In the *follow-up study during treatment*, our study revealed that the results of PET and CT were concordant in 44 patients [12 complete responses (CR), 24 partial responses (PR), and 8 progressive diseases (PD)]. For the rest of the cases (45% of our cases, $n = 36$), the therapeutic response was different.

While at the end of treatment assessment, the results of PET and CT were concordant in 52 patients [20 CR, 12 PR, and 20 PD]. For the rest of the cases (35% of our cases, $n = 28$), the therapeutic response differed. Thus, PET/CT and contrast-enhanced computed tomography were concurrent in results in 55% of cases during treatment and 75% at the end of treatment with CT sensitivity of 61.1%, specificity of 92.2%, and accuracy of 76.2%
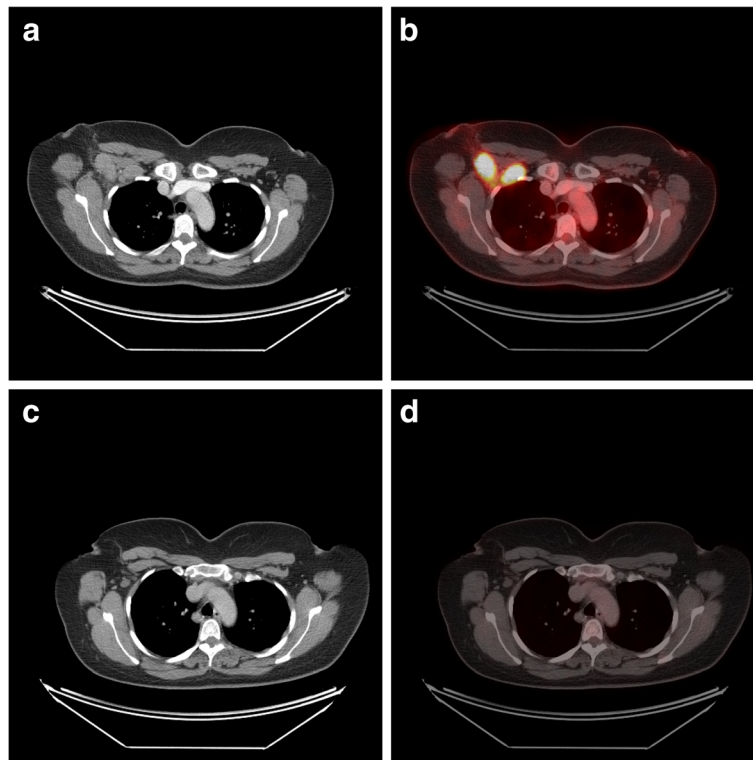
Fig. 5 A 37-year-old patient, newly diagnosed Hodgkin lymphoma. **a**, **b** His initial study revealed multiple metabolically active FDG avid lymph nodes which are seen at right axillary lymph nodes, largest measures 3.5 × 2.6 cm with SUV max 7.05. **c**, **d** His interment study reveals complete metabolic resolution; however, anatomically still non-FDG avid axillary lymph nodes are noted that have markedly regressed in size; the largest measures 1.6 × 0.65 cm compared to 3.5 × 2.6 cm in previous study. This study was partial regression by CT and total regression by PET

during treatment in comparison to 100% sensitivity and specificity of PET/CT, while sensitivity of CT at end of treatment is 57.5% with specificity of 86.7% and accuracy of 71.6%. This is in keeping with the multicenter study; comparison of FDG PET/CT and 64-slice multi-detector-row CT was done in initial staging and response evaluation at the end of treatment in patients with lymphoma by Gómez León et al. [13]; 181 patients were enrolled; their results confirmed that FDG PET/CECT was clearly superior to ceCT64 for EOT evaluation ($P < 0.05$). Using FDG PET/CT, there was concordance with the reference standard in 97.8% of the cases (88/90) with $\kappa = 0.91$ ($P < 0.001$), corresponding with a CR in 83.3% ($n = 75$), a PR in 4.4% ($n = 4$), and a PD in 10% ($n = 9$), with good sensitivity and specificity for response assessment. As compared to CECT, there was concordance with the reference standard in 78% of cases (71/91).

Our results are also matching a study done by Othman et al. [14] were 100 patients were enrolled and showed poor agreement between PET/CT and CECTs ($k = 0.32$).

Similar results were also obtained in the study by Le Dortz et al. [15]. They retrospectively evaluated the usefulness of positron emission tomography/computed tomography in staging, prognosis evaluation and restaging of patients with follicular lymphoma. In 45 patients, the accuracy of PET/CT for therapeutic response assessment was higher than that of CT (0.97 vs 0.64), especially due to its ability to identify inactive residual masses.

In a study by Omar et al. [11], the study included 50 patient PET/CTs in initial staging and therapy response assessment of lymphoma compared to contrast-enhanced CT. In the follow-up study during chemotherapy cycles, 18F-FDG PET/CT and CECT were concurrent in results in 11 cases (61%) and discordant in 7 cases (39%). In the follow-up study after the end of chemotherapy cycles, 18F-FDG PET/CT and CECT were concurrent in results in 9 cases (44%) and discordant in 11 cases (56%).

In a study done by Najjar et al. [16], the sensitivity and specificity were 87% and 100% for FDG-PET, 100% and 100% for physical examination, and 90% and 100% for CT, respectively. In addition, 42 of 97 peripheral lymph node lesions observed by FDG-PET were clinically undetected, whereas the physical examination detected 23 additional nodal lesions. PET and CT both indicated 12 extranodal lymphomatous localizations. FDG-PET

Table 7 Relation between end of treatment at CT and end of treatment at PET of the study group

End of treatment at PET	End of treatment at CT								Total		Chi-square test	
	Complete regression		Progression disease		Partial regression		Stationary disease					
	No.	%	No.	%	No.	%	No.	%	No.	%	χ^2	P value
Complete regression	5	25.0	1	5.0	1	5.0	2	10.0	9	45.0	27.005	< 0.001**
Progression disease	0	0.0	5	25.0	0	0.0	2	10.0	7	35.0		
Partial regression	0	0.0	0	0.0	3	15.0	0	0.0	3	15.0		
Stationary disease	0	0.0	0	0.0	0	0.0	1	5.0	1	5.0		
Total	5	25.0	6	30.0	4	20.0	5	25.0	20	100.0		

χ^2, Chi-square test; **P value < 0.001 HS
This table shows statistically significant relation between end of treatment at CT and end of treatment at PET of the study group

showed 7 additional extranodal lesions while 5 additional unconfirmed lesions were observed on CT.

In a study by El Refaei et al. [17] by PET/CT, 38.5% of the studied population had complete response, 38.5% had partial response, 10.3% had stable disease, and 12.8% had metabolic progression. Morphologic response on CT showed that 30.8% of the studied population had complete response, 48.7% had partial response, 10.3% had stable disease, and 10.3% had morphologic progression.

According to Gómez León et al. [13], the most frequent reason for the overestimation in CECT of response was the detection of residual lymphadenopathy of pathological size lacking malignant infiltration. Regarding the extra nodal lesions, the most frequent reason for incorrectly detecting lymphomatous infiltration in the lung was the detection of nonspecific inflammation

The study by Tatsumi et al. [18], 48 sites exhibited discordant findings: 34 sites as PET positive and CT negative and 14 sites as PET negative and CT positive. Among the PET-positive and CT-negative sites, patients had negative CT findings because of the size criterion (more than 10 mm in short axis was considered positive).

In a study done by Fueger et al. [19], PET/CT correctly diagnosed 92 nodal regions as positive for

Table 8 End of treatment distribution of the study group

	Number	Percent
CT		
Complete regression	5	25.0
Progression disease	6	30.0
Partial regression	4	20.0
Stationary disease	5	25.0
PET		
Complete regression	9	45.0
Progression disease	7	35.0
Partial regression	3	15.0
Stationary disease	1	5.0

lymphomatous involvement and 458 as disease free vs 68 and 449 for PET and 64 and 459 for CT, respectively. The respective sensitivities, specificities, and accuracies were 99%, 100%, and 99.8% for PET/CT; 68%, 97.5%, and 92.2% for PET; and 70%, 100%, and 94.7% for CT. PET/CT performed significantly better than PET (P < 0.001 for sensitivity, specificity, and accuracy) and CT (P < 0.001 for sensitivity and accuracy). PET/CT also correctly identified significantly more extranodal lesions (22) than CT (14) and PET (nine).

In cases with PET-negative and CT-positive sites, the patients were considered to have nonviable fibrotic tissue according to clinical information, including follow-up imaging results.

It has been known for many years that CT assessment is not sensitive for tumoral foci that are less than 10 mm in diameter, but no other alternative method than size criteria has been consistently adopted.

Being aware of normal FDG distribution and physiological FDG uptake is of utter importance in oncologic PET/CT examinations. To avoid false-positive and false-negative results, interpreting the CT and PET findings should be done carefully [20].

Since PET/CT provides both metabolic as well as morphologic data for each lesion, new criteria for diagnosing small foci of malignancy may be suggested with this modality.

Conclusion

PET/CT using 18F-FDG is considered one of the leading oncologic imaging modality at the present time with valuable applications in lymphoma. It is very efficient with less pitfalls and false results compared to both its components interpreted separately.

PET/CT can accurately detect the therapeutic response in lymphoma both early (interim study) as well as late (end of treatment study) with higher sensitivity than CECT as it removed the usual weaknesses of conventional imaging by combining both anatomical and metabolical information.
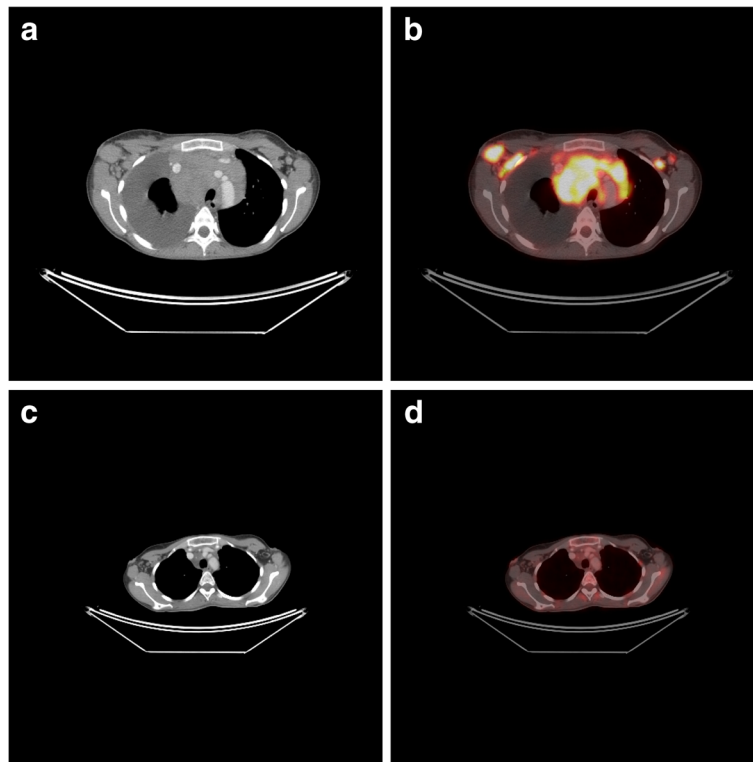
Fig. 6 A 19-year-old female patient, known case of HL. Pre-treatment PET-CT images (**a**, **b**) show multiple amalgamated hypermetabolic FDG avid lymph nodes. PET CT images at follow-up (**c**, **d**) show marked regression of the size and the number of the lymph nodes; all of them show no metabolic activity. The patient was categorized as partial regression on CT and complete regression on PET/CT

We recommend using PET/CT in assessing the treatment response in all lymphoma cases. PET/CT is becoming a standard modality for lymphoma providing a new vision to management and treatment plan.

We acknowledge some limitations in current study as small number of subjects enrolled in this study and the lack of biopsy. Also, the patient population studied was heterogeneous, and larger studies evaluating the individual subtypes might be needed to confirm our results.

Abbreviations
CR: Complete responses; PR: Partial responses; PD: Progressive diseases; PET/CT: Positron emission tomographic/Computed tomographic; FDG: Fluorodeoxyglucose; PET: Positron emission tomographic; CT: Computed tomographic; CECT: Contrast-enhanced computed tomography

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