Comparison of ^{18}F-FDG PET/CT and CT: Diagnosis Performance in Lymphoma Patient after Treatment

Sunanta Chiewvit MD*, Kullathorn Thephamongkhol MD**,
Kritaya Ubolnuch MNS*, Julaporn Pooliam MSc***,
Nopparat Phongsawat BSc*, Pipat Chiewvit MD****

** Division of Nuclear Medicine, Department of Radiology, Siriraj Hospital, Mahidol University, Bangkok, Thailand*
*** Division of Radiotherapy, Department of Radiology, Siriraj Hospital, Mahidol University, Bangkok, Thailand*
**** Clinical Epidemiology Unit, Office for Research and Development, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand*
***** Division of Diagnosis Radiology, Department of Radiology, Siriraj Hospital, Mahidol University, Bangkok, Thailand*

Objective: *Retrospectively comparing ^{18}F-FDG PET/CT and CT findings at the same anatomic locations in patients with lymphoma by using a combined PET/CT scanner and to analyze the lesions on both metabolic and anatomic bases to evaluate their sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy. We analyzed all studies, all patients, common cell type in this study such as diffuse large B cell lymphoma (DLBCL) and Hodgkin's lymphoma and indication of the study such as restaging for recurrence post-therapy and evaluate residual disease within two months after chemotherapy.*

Material and Method: *Sixty-seven lymphoma patients were studied PET/CT between January 2007 and December 2012 in Siriraj Hospital. We excluded six patients due to no medial report in our hospital. Sixty-one patients (29 male, 32 female, mean age 46.6±17.7 years, range 8-75) with NHL and with HL) were analyzed for the result of dual-modality PET/CT. They underwent 77 ^{18}F-FDG PET/CT studies for restaging, for recurrence post-therapy based on 41 studies and evaluation of residual disease within two months after chemotherapy in 36 studies.*

Results: *The statistical parameters of ^{18}F-FDG PET/CT imaging of lymphoma patients after treatment show significantly better specificity than CT and insignificant high accuracy for all studies, all patients, histology of DLBCL, indication of evaluation of active lymphoma within two months after chemotherapy. The ^{18}F-FDG PET/CT parameters of accuracy and PPV are higher than CT without statistical significance. The ^{18}F-FDG PET/CT is not significantly better than CT for histology of Hodgkin's lymphoma and indication of restaging for recurrence post-therapy. Nevertheless, the ^{18}F-FDG PET/CT shows slightly improved specificity, PPV, and accuracy than CT. The sensitivity of CT in this study is high and may be from most of our cases selected post-treatment lymphoma that had a residual mass after treatment. Therefore, the sensitivity of PET scan is not significantly higher when compared with CT scan.*

Conclusion: *The PET/CT is better than CT for post-treatment lymphoma patient particularly for cell type of DLBCL and indication for evaluation of active lymphoma within two months after chemotherapy.*

Keywords: *^{18}F-FDG PET/CT, Lymphoma*

J Med Assoc Thai 2014; 97 (1): 85-94
Full text. e-Journal: *http://www.jmatonline.com*

^{18}F-FDG PET/CT is a functional imaging modality. ^{18}F-FDG is a glucose analogue uptake is directly proportional to the glucose metabolism of tumor tissue. Malignant lymphoma with high glucose metabolism show preferential uptake of FDG as compared to surrounding normal cells. ^{18}F-FDG PET/CT is used nowadays for initial staging, monitoring the response to therapy and restaging after treatment of patients with Hodgkin's lymphoma (HL) and high-grade non-Hodgkin's lymphoma (NHL).

Following therapy, a large number of patients were left with residual masses. These are particularly frequent in patients with initial mediastinal disease, since PET assesses metabolic activity in active lymphoma. PET has a much greater specificity than CT in this setting. PET appears to be helpful in identifying the presence of residual disease. Therefore, it may allow either directed biopsies to be performed or consolidation treatment with chemotherapy and/or irradiation. ^{18}F-FDG PET/CT has been introduce into the evaluation of patient with lymphoma, although

Correspondence to:
Chiewvit S, Division of Nuclear Medicine, Department of Radiology, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.
Phone: 089-503-0484
E-mail: schiewvit1@hotmail.com

some papers from many countries have demonstrated that ^{18}F-FDG PET/CT has greater sensitivity and specificity than CT concerning the indication of initial staging, restaging for recurrence post-therapy, and evaluated residual disease after chemotherapy[1,2]. Due to the high cost of a ^{18}F-FDG PET/CT study and not being reimbursable by the Thailand government, this study was desirable for the advantage of ^{18}F-FDG PET/CT over CT in the sense of indication and cell types in order to select appropriate patients for the highest utility.

The purpose of the present study was to compare ^{18}F-FDG PET/CT and CT findings at the same anatomic locations in patients with lymphoma by using a combined PET/CT scanner to analyze the lesions on both metabolic and anatomic bases and evaluate the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy. The authors analyzed all studies, all patients, common cell types in this study such as diffuse large B cell lymphoma (DLBCL) and Hodgkin's lymphoma and indication of the study such as restaging for recurrence post-therapy and evaluated residual disease within two months after chemotherapy.

Material and Method

The retrospective data of 67 lymphoma patients were studied PET/CT between January 2007 and December 2010 in Siriraj Hospital. We excluded six patients due to no medical report in our hospital. Sixty-one patients were analyzed. Dual-modality PET/CT was performed on a Discovery STE 16 (General Electric Medical Systems, Milwaukee, WI, USA). PET imaging was conducted one hour after the administration of 10 to 13 mCi (5 minute/bed position from base of skull to upper thigh). The non-contrast or contrast CT images were used for PET attenuation correction and anatomical information correlation. All patient blood/sugar was below 200 mg%.

Data analysis

The result of CT positive is the abnormal mass or enlargement of lymph node review by diagnosis radiologist. The PET positive lesion is avid of glucose tracer higher than background or normal organ activity. Retrospective review of PET and CT finding were compared with the gold standard. The gold standard results defined as a clinical follow-up for at least 12 months. The gold standard negative was defined as non-active or mass enlargement or new lesions or clinically uncompleted remission in the follow-up for at least 12 months without any treatment performed in 44 studies. Two studies of gold standard negative are the diagnosis of tuberculosis (TB) by tissue biopsy. The gold standard positive was defined as tumor progression by anatomical imaging in eight studies and clinician decision to treat active lymphoma in 30 studies with 26 studies responsive to treatment and four studies showing progression to a new, metastasized lesion.

Statistical analysis, sensitivity, specificity, accuracy, PPV, and NPV with 95% CI of the PET/CT and CT findings were calculated from the comparison data with gold standard. The calculation was categorized by patient, by study, by indication (restaging for recurrence post-therapy and evaluated residual disease within 2 months after chemotherapy), and Histology (Hodgkin's lymphoma, non-Hodgkin's lymphoma-DLBCL).

Statistical analysis

Statistical parameters of sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) were obtained in all studies, all patients, subgroups of common histology (DLBCL and Hodgkin's lymphoma), subgroups of indication (restaging for recurrence post-therapy and evaluated residual disease within 2 months after chemotherapy). For the initial staging, we used descriptive analysis due to the limit in the number of patients. Finally, the authors calculated the significant advantage of the study by McNemar test. A p-value of less than 0.05 was considered to indicate a significant difference.

Ethics considerations

The study was under approval from Siriraj Institutional Review Board, Faculty of Medicine, Siriraj Hospital, Mahidol University.

Results

Sixty-one patients (29 male, 32 female, mean age 46.6±17.7 years, range 8-75) with NHL and with HL, who underwent 77 ^{18}F-FDG PET/CT studies were analyzed for restaging in 41 studies of recurrence post-therapy and evaluated for residual disease within two months after chemotherapy in 36 studies.

The statistical parameters of ^{18}F-FDG PET/CT imaging of lymphoma patients after treatment are presented in the Table 1-6.

The sensitivity of CT in this study is high. This may be because most of the cases were selected post-treatment lymphoma that had a residual mass

Table 1. Comparison statistical parameters of CT and PET/CT studies for all studies (74 studies)

Parameter	CT	PET/CT	p-value[#]
Sensitivity	29/31 = 93.5% (82.7%, 98.5%)	27/31 = 87.1% (75.9%, 95.8%)	0.500
Specificity	22/46 = 47.8% (34.1%, 61.9%)	32/46 = 69.6% (55.2%, 80.9%)	0.006
PPV	29/53 = 54.7% (47.4%, 71.4%)	27/41 = 65.9% (56.8%, 81.8%)	-
NPV	22/24 = 91.7% (74.2%, 97.7%)	32/36 = 88.9% (74.7%, 95.6%)	-
Accuracy	51/77 = 66.2% (58.5%, 77.9%)	59/77 = 76.6% (68.7%, 86.0%)	0.057

[#] McNemar test
The ^{18}F-FDG PET/CT is statistical better specificity than CT for all studies. The accuracy of ^{18}F-FDG PET/CT is slightly improve as compare with CT result but it is not statistical significant.
PPV = positive predictive value; NPV = negative predictive value

Table 2. Comparison statistical parameters of CT and PET/CT studies for all patients (61 patients)

Parameter	CT	PET/CT	p-value[#]
Sensitivity	31/32 = 96.9% (84.3%, 99.4%)	29/32 = 90.6% (75.8%, 96.8%)	0.500
Specificity	13/29 = 44.8% (28.4%, 62.5%)	22/29 = 75.9% (57.9%, 87.8%)	0.004
PPV	31/47 = 66.0% (51.7%, 77.8%)	29/36 = 80.6% (65.0%, 90.2%)	-
NPV	13/14 = 92.9% (68.5%, 98.7%)	22/25 = 88.0% (70.0%, 95.8%)	-
Accuracy	44/61 = 72.1% (59.8%, 81.8%)	51/61 = 83.6% (72.4%, 90.8%)	0.065

[#] McNemar test
The ^{18}F-FDG PET/CT is statistical better specificity than CT for all patients. The accuracy of ^{18}F-FDG PET/CT is slightly improve as compare with CT result but it is not statistical significant.

Table 3. Comparison statistical parameters of CT and PET/CT studies for the patient with DLBCL (42 studies)

Parameter	CT	PET/CT	p-value[#]
Sensitivity	17/18 = 94.4% (74.2%, 99.0%)	16/18 = 88.9% (67.2%, 96.9%)	1.000
Specificity	11/24 = 45.8% (27.9%, 64.9%)	18/24 = 75.0% (55.1%, 88.0%)	0.039
PPV	17/30 = 56.7% (39.2%, 72.6%)	16/22 = 72.7% (51.8%, 86.8%)	-
NPV	11/12 = 91.7% (64.6%, 98.5%)	18/20 = 90.0% (69.9%,97.2%)	-
Accuracy	28/42 = 66.7% (51.6%, 79.0%)	34/42 = 80.9% (66.7%, 90.0%)	0.109

[#] McNemar test
The ^{18}F-FDG PET/CT is statistical better specificity than CT for DLBCL patients.
DLBCL = diffuse large B cell lymphoma

Table 4. Comparison statistical parameters of CT and PET/CT studies for the patient with Hodgkin's lymphoma (16 studies)

Parameter	CT	PET/CT	p-value[#]
Sensitivity	6/6 = 100.0% (61.0%, 100.0%)	5/6 = 83.3% (43.6%, 97.0%)	1.000
Specificity	5/10 = 50.0% (23.7%, 76.3%)	7/10 = 70.0% (39.7%, 89.2%)	0.500
PPV	6/11 = 54.5% (28.0%, 78.7%)	5/8 = 62.5% (30.6%, 86.3%)	-
NPV	5/5 = 100.0% (56.6%, 100.0%)	7/8 = 87.5% (52.9%, 97.8%)	-
Accuracy	11/16 = 68.8% (44.4%, 85.8%)	12/16 = 75.0% (50.5%, 89.8%)	1.000

[#] McNemar test
The ^{18}F-FDG PET/CT is not significant better than CT for histology of Hodgkin's lymphoma in all parameter

Table 5. Comparison statistical parameters of CT and PET/CT studies for the indication of restaging for recurrence post-therapy (41 studies)

Parameter	CT	PET/CT	p-value#
Sensitivity	13/15 = 86.7% (62.1%, 96.3%)	13/15 = 86.7% (62.1%, 96.3%)	1.000
Specificity	14/26 = 53.8% (35.5%, 71.2%)	18/26 = 69.2% (50.0%, 83.5%)	0.219
PPV	13/25 = 52.0% (33.5%, 70.0%)	13/21 = 61.9% (40.9%, 79.2%)	-
NPV	14/16 = 87.5% (64.0%, 96.5%)	18/20 = 90.0% (69.9%, 97.2%)	-
Accuracy	27/41 = 65.8% (50.6%, 78.4%)	31/41 = 75.6% (60.7%, 86.2%)	0.219

McNemar test

The ^{18}F-FDG PET/CT is not significant better than CT indication of restaging for recurrence post-therapy in all parameter

Table 6. Comparison statistical parameters of CT and PET/CT studies for the indication of evaluation active lymphoma within 2 months after chemotherapy (36 studies)

Parameter	CT	PET/CT	p-value#
Sensitivity	18/18 = 100.0% (82.4%, 100.0%)	16/18 = 88.9% (67.2%, 96.9%)	0.500
Specificity	8/18 = 44.4% (24.6%, 66.3%)	14/18 = 77.8% (54.8%, 91.0%)	0.031
PPV	18/28 = 64.3% (45.8%, 79.3%)	16/20 = 80.0% (58.4%, 91.9%)	-
NPV	8/8 = 100.0% (67.6%, 100.0%)	14/16 = 87.5% (64.0%, 96.5%)	-
Accuracy	26/36 = 72.2% (56.0%, 84.2%)	30/36 = 83.3% (68.1%, 92.1%)	0.289

McNemar test

The ^{18}F-FDG PET/CT is statistical better specificity than CT for indication of evaluation active lymphoma within 2 months after chemotherapy.

after treatment. Therefore, the sensitivity of PET scan is not significant high compared with CT scan.

Discussion

Several reports have demonstrated ^{18}F-FDG PET/CT imaging shows significantly accurate staging and the ability to upstage disease. FDG-PET results in a modification of disease stage (usually upstaging) in about 15 to 20% of patients with an impact on management in about 5 to 15%[3]. In this study, the ^{18}F-FDG PET/CT imaging and CT imaging have the same abnormal finding and same staging. This indicates ^{18}F-FDG PET/CT imaging does not get more information than CT for initial study. However, the limit of the study is the small number of subjects.

The study by Yi J[4] retrospectively analyzed 42 patients with primary gastric lymphoma who underwent PET/CT scans; 32 patients with DLBCL and 10 patients with extranodal marginal zone B-cell lymphoma of mucosa-associated lymphoid tissue (MALT lymphoma). The result reveals nine patients up-staged based on the results of their PET/CT scan compared to CT (7 DLBCL, 2 MALT lymphomas) while six patients down-staged by the PET/CT scan.

The previous paper about PET/CT and CECT studies for DLBCL 31 patients after therapy by Chong E[5]. The calculated sensitivity by site of lesion analysis of PET/CT and CECT (contrast enhance CT) studies are 93% (51/55) and 78% (43/55), respectively. PET/CT imaging is superior to CECT and PET/CT can replace CECT in diffuse large B-cell lymphoma. This study shows the result that PET/CT better than CT in specificity with statistic significant. However, the sensitivity for CT of this study is high due to selection of patients with mass on CT after treatment.

The systematic review of PET of HL after completed therapy by Jerusalem G[6] with adaptation by author is present in Table 7.

Staging of patients with recurrent lymphoma has a great clinical impact on the choice of treatment regimen and survival. The early detection and early treatment make a good prognostic, with the hope of prolonged survival and potential cure.

The previous studies of ^{18}F-FDG PET/CT for the indication of restaging for recurrence post-therapy and the comparison with this study for statistic parameters are present in the Table 8.

The present study shows that PET/CT scan for the indication of restaging improve specificity as

Table 7. Systematic review of PET of HL after completed therapy by Jerusalem G[6] with adapt by author

Study	F/U (month)	Sen (%)	Spec (%)	PPV (%)	NPV (%)	Accuracy (%)
de Wit[7]	26	100 (10/10)	78 (18/23)	67 (10/15)	100 (18/18)	85 (28/33)
Dittmann[8]	6	87 (7/8)	94 (17/18)	87 (7/8)	94 (17/18)	92 (24/26)
Spaepen[9]	32	50 (5/10)	100 (50/50)	100 (5/5)	91 (50/55)	92 (55/60)
Weihrauch[10]	28	67 (6/9)	80 (16/20)	60 (6/10)	84 (16/19)	76 (22/29)
Guay[11]	16	79 (11/14)	97 (33/34)	92 (11/12)	92 (33/36)	92 (44/48)
Friedberg[12]	24	80 (4/5)	85 (23/27)	50 (4/8)	96 (23/24)	84 (27/32)

F/U = median follow-up; Sen = sensitivity; Spec = specificity; PPV = positive predictive value; NPV = negative predictive value; HL = Hodgkin's lymphoma

Table 8. Statistic parameters of ^{18}F-FDG PET/CT for the indication of restaging for recurrence post-therapy and the comparison with this study

Imaging modality	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Freudenberg LS[15] 27 HL and NHL patients					
CT	78.0	54.0	65.0	70.0	67.0
PET/CT	93.0	100.0	100.0	93.0	96.0
Filmont JE[16] 32 HL patients					
CT	-	-	50.0	100.0	66.0
PET	-	-	79.0	86.0	91.0
Reinhardt MJ[17] 40 HL and 61 NHL patients					
CT	17.9	100.0	100.0	76.0	77.2
PET	71.4	94.5	83.3	9.6	88.1
Mikosch P[18] 44 HL and 49 NHL patients					
CT	88.0	35.0	-	-	56.0
PET	91.0	81.0	-	-	85.0
Cerci JJ[19] 130 HL patients					
CT	87.0	73.6	51.9	94.5	77.5
PET	100.0	92.0	92.3	100.0	95.9
This study					
CT	86.7	53.8	52.0	87.5	65.8
PET/CT	86.7	69.2	61.9	90.0	75.6

HL = Hodgkin's lymphoma; NHL = non-Hodgkin's lymphoma

compare to CT study like other studies, except Reinhardt MJ study. For sensitivity, this study reveals PET/CT and CT had the same value. It seems the PET/CT slightly improved PPV, NPV and accuracy but not statistical significant. The result from Cerci JJ[19] suggests ^{18}F-FDG-PET is highly cost effective and would reduce costs for the public health care program in Brazil.

Residual masses detected after completion of therapy for aggressive lymphomas. They are quite common, especially in patients with a large tumor burden in the mediastinum and abdomen.

A major diagnostic challenge is posed by post-therapeutic non-viable residual masses, which can be demonstrated by radiological imaging up to residual thoracic masses. They are present in about one-third of patients after treatment for NHL or HD[20].

The goal of imaging technique at the end of first line treatment is an accurate assessment of treatment response and can predict disease relapse. The result permits quick initiation of a second line therapy for in-patient suffering from progressive disease or unresponsive to treatment, and to avoid over-treatment of patients in complete remission or those having a non-active residual disease. The previous studies[20,21] showed that PET has a higher specificity than CT in predicting relapses like the present study.

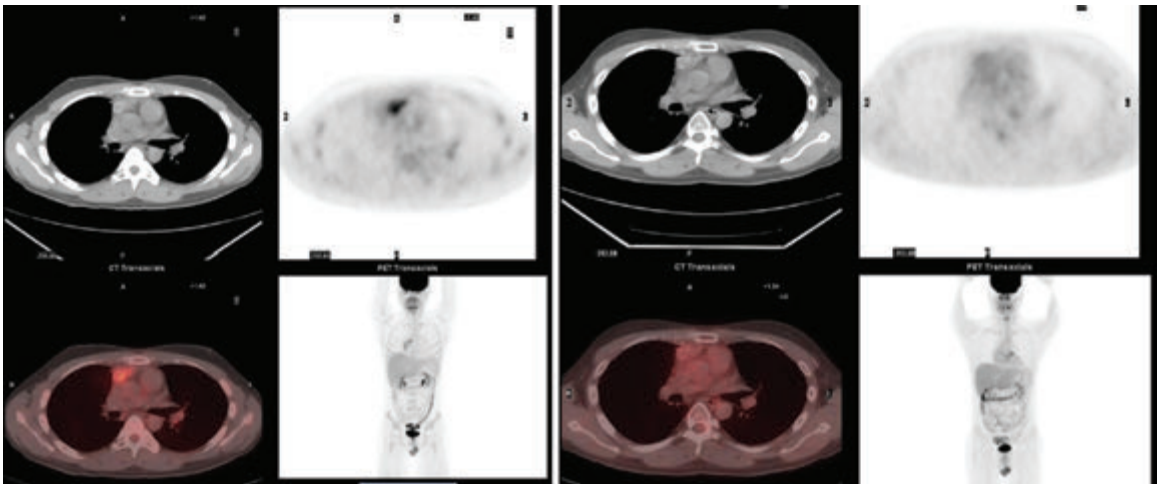

Fig. 1-2 A 29-year-old man diagnosis of DLBCL after R-CHOP reveals anterior mediastinal mass with calcification (true positive) the PET scan in Fig. 1 reveals hypermetabolic active lymphoma at anterior mediastinum then the patient was treatment with radiotherapy, rituximab and cyclophosphamide. After treatment, the patient received follow-up PET/CT in Fig. 2. The CT show insignificant change in size (false positive) but this mass PET show no glucose avidity (true negative), compatible with completed response to treatment. The follow-up at least 29 months without any treatment find the patient in complete remission.

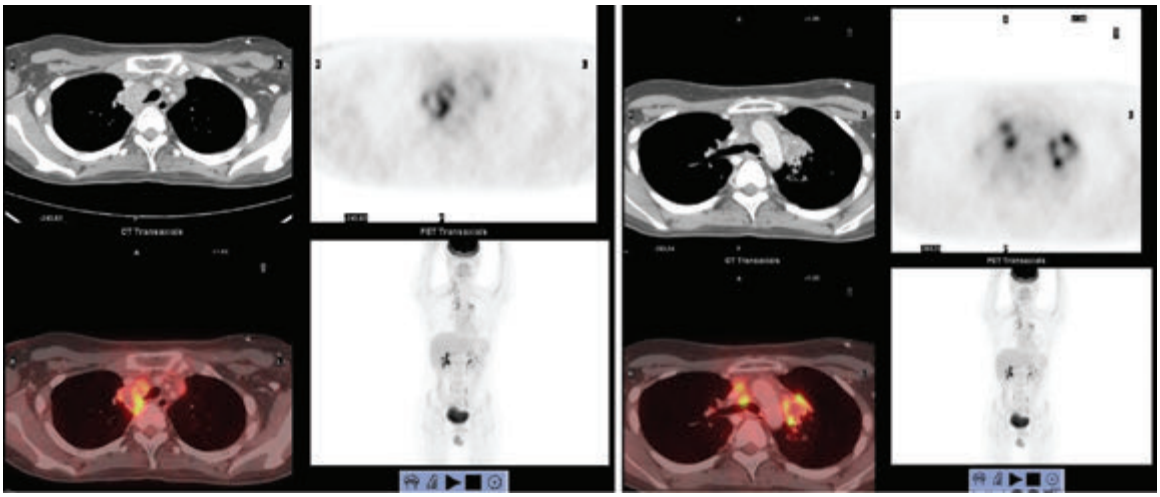

Fig. 3-4 A 14-year-old boy diagnosis of HL stage IIb post chemotherapy, BMT and pulmonary TB post completed treatment. The PET/CT reveals matted lymphadenopathy at paratrachal and prevascular with inhomogeneous moderate increased glucose activity (both CT and PET scan are false positive). The tissue biopsy at lymph node is compatible with TB.

The study by Rigacci L[22] shows the superiority of PET compared with conventional imaging methods in 28 patients following the end of their treatment with median follow-up period of 45 months. Fifteen patients out of the 28 (54%) had positive CT scans while 13 (46%) had negative ones. Eleven patients out of the 15 CT positive (73%) had negative PET scans and no relapse. The remaining four patients (27%) had positive PET scans with only one relapse (25%). With respect to the 13 patients who had negative CT scans, nine patients (69%) had negative PET scans and no relapse. The remaining four patients (31%) had positive PET scans with three relapse cases (75%). Overall sensitivity of the CT and the PET were 25 and 100%, respectively, specificity 42 and 83%, respectively, positive predictive

value (PPV) 7 and 50%, respectively, negative predictive value (NPV) 77 and 100%, respectively, and accuracy 39 and 86%, respectively. FDG-PET results are predictors of prognosis giving 100% disease-free survival in PET negative patients and 54% disease-free survival in PET positive patients.

The superior specificity of PET/CT compared with conventional imaging methods in the present study reflects the ability of PET/CT to detect active disease in abnormal residual masses on CT post-treatment. These results suggest that PET/CT may be a useful test for baseline evaluation after first-line therapy and can help identify patients with active residual disease in whom further therapy may be needed. The sensitivity of PET/CT is lower than CT may be due to reduced metabolic activity after chemotherapy as shown in Fig. 5. The appropriate time for PET/CT to detect active disease after finish chemotherapy to evaluate treatment response could be six to eight weeks after treatment to reduce effect of chemotherapy inhibit FDG uptake.

The prospective study by Talavera Rubio MP[23] 94 studies belonging to 78 patients, 47 men and 31 women with a mean age of 49.9 years (range: 17-83), were analyzed. Thirty-six patients were diagnosed with Hodgkin's lymphoma and 42 of non-Hodgkin's lymphoma (NHL). Of these, 27 were high grade and 15 low grade. The reason for the request was staging (8), evaluation of response at the end of the chemotherapy treatment (29), suspicion of recurrence (9) and control of remission (48). The results are presented in the Table 9.

According to Talavera Rubio MP[23] study, initial staging discovery slightly improves diagnosis with PET/CT. As to indications of possible recurrence, PET/CT is no better than CT; however, this study demonstrates that the result of PET/CT is slightly better for specificity, PPV and NPV than CT, but it is not statistical significant. The Talavera Rubio MP[23] study shows PET/CT for evaluation of response at the end of the chemotherapy treatment detect PPV is

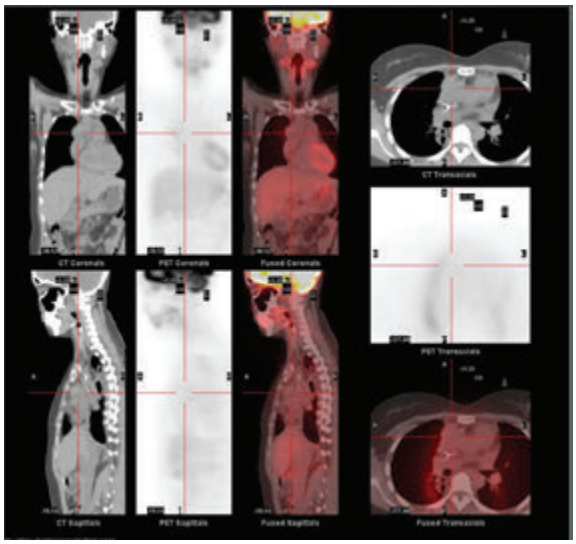

Fig. 5 A 28-year-old woman known case of HL post chemotherapy and relapse at anterior mediastinum mass start salvage chemotherapy 3 courses one month after salvage chemotherapy the PET/CT scan reveals no uptake in anterior mediastinum mass (CT is true positive, PET is false negative). The follow-up CT at 6 months lateral show increased in size of anterior mediastinum mass. The false negative of PET may be from recent chemotherapy. The effect of chemotherapy can inhibit uptake of glucose metabolism of tumor mass.

Table 9. Statistic parameters of PET/CT and CECT in all of the patients and in each group indication analyzed by Talavera Rubio MP study comparison with this study

Parameter	Staging (%)		Suspicion of recurrence (%)		Evaluation of response (%)		Control of remission (%)		Total (%)	
	PET/CT	CT	PET/CT	CT	PET/CT	CT	PET/CT	CT	PET/CT	CT
Talavera Rubio MP study										
Sensitivity	95.9	93.8	80.7	92.5	95.5	94.8	100.0	93.0	100.0	94.0
Specificity	100.0	98.8	94.6	96.4	98.5	94.6	99.0	98.5	98.0	97.0
PPV	100.0	95.8	63.6	75.7	79.6	47.4	45.8	33.3	77.0	62.0
NPV	98.8	98.2	97.7	99.0	99.7	99.7	100.0	100.0	99.0	99.0
This study										
Sensitivity	-	-	86.7	86.7	88.9	100.0	-	-	90.6	96.9
Specificity	-	-	69.2	53.8	77.8	44.4	-	-	75.9	44.8
PPV	-	-	61.9	52.0	80.0	64.3	-	-	80.6	66.0
NPV	-	-	90.0	87.5	87.5	100.0	-	-	88.0	92.9

significantly better than CT identical to this study, but this study shows improved specificity too. For the total of all studies, the PET/CT indicates improved sensitivity and PPV by the Talavera Rubio MP[23] study. In this study, the PET/CT exhibits significantly improved specificity, PPV and accuracy.

According to the PET/CT study for lymphoma, patients cannot be reimbursed in Thailand. The information from the present study reveals the PET/CT study is valuable for an indication of restaging, especially in the case of DLBCL and the indication for treatment response within two months after completion of chemotherapy. For increased specificity and accuracy, this helps decrease futile chemotherapy and reduce the cost of treatment. Reimbursement should be considered for these indications.

Conclusion

The PET/CT is better than CT for post-treatment, lymphoma patient, particularly for cell type of DLBCL, and indication for evaluation of active lymphoma within two months after chemotherapy. The specificity shows statistically significant improvement for PET/CT as compared with CT.

Acknowledgement

The authors wish to thank Prof. Dr. med. Benno von Bormann for his suggestions in completing this paper.

Potential conflicts of interest

None.

References

1. Cronin CG, Swords R, Truong MT, Viswanathan C, Rohren E, Giles FJ, et al. Clinical utility of PET/CT in lymphoma. AJR Am J Roentgenol 2010; 194: W91-103.
2. Seam P, Juweid ME, Cheson BD. The role of FDG-PET scans in patients with lymphoma. Blood 2007; 110: 3507-16.
3. Juweid ME. FDG-PET/CT in lymphoma. Methods Mol Biol 2011; 727: 1-19.
4. Yi J, Kim S, Lee S, Park S, Ko Y, Choi J, et al. Clinical usefulness of PET/CT in initial staging and response evaluation of primary gastric lymphoma. 2009 ASCO Annual Meeting. J Clin Oncol 2009; 27 (Suppl Abstr): e19541.
5. Chong E, Torigian D, Mato A, Downs L, Alavi A, Schuster S. Comparison of contrast-enhanced CT (CECT) and FDG-PET/CT for imaging diffuse large B-cell lymphoma (DLBCL), follicular lymphoma (FL), and chronic lymphocytic leukemia/small lymphocytic lymphoma (CLL/SLL). J Nucl Med 2009; 50 (Suppl 2): 1671.
6. Jerusalem G, Hustinx R, Beguin Y, Fillet G. Evaluation of therapy for lymphoma. Semin Nucl Med 2005; 35: 186-96.
7. de Wit M, Bohuslavizki KH, Buchert R, Bumann D, Clausen M, Hossfeld DK. 18FDG-PET following treatment as valid predictor for disease-free survival in Hodgkin's lymphoma. Ann Oncol 2001; 12: 29-37.
8. Dittmann H, Sokler M, Kollmannsberger C, Dohmen BM, Baumann C, Kopp A, et al. Comparison of 18FDG-PET with CT scans in the evaluation of patients with residual and recurrent Hodgkin's lymphoma. Oncol Rep 2001; 8: 1393-9.
9. Spaepen K, Stroobants S, Dupont P, Thomas J, Vandenberghe P, Balzarini J, et al. Can positron emission tomography with [(18)F]-fluorodeoxyglucose after first-line treatment distinguish Hodgkin's disease patients who need additional therapy from others in whom additional therapy would mean avoidable toxicity? Br J Haematol 2001; 115: 272-8.
10. Weihrauch MR, Re D, Scheidhauer K, Ansen S, Dietlein M, Bischoff S, et al. Thoracic positron emission tomography using 18F-fluorodeoxyglucose for the evaluation of residual mediastinal Hodgkin disease. Blood 2001; 98: 2930-4.
11. Guay C, Lepine M, Verreault J, Benard F. Prognostic value of PET using 18F-FDG in Hodgkin's disease for posttreatment evaluation. J Nucl Med 2003; 44: 1225-31.
12. Friedberg JW, Fischman A, Neuberg D, Kim H, Takvorian T, Ng AK, et al. FDG-PET is superior to gallium scintigraphy in staging and more sensitive in the follow-up of patients with de novo Hodgkin lymphoma: a blinded comparison. Leuk Lymphoma 2004; 45: 85-92.
13. Panizo C, Perez-Salazar M, Bendandi M, Rodriguez-Calvillo M, Boan JF, Garcia-Velloso MJ, et al. Positron emission tomography using 18F-fluorodeoxyglucose for the evaluation of residual Hodgkin's disease mediastinal masses. Leuk Lymphoma 2004; 45: 1829-33.
14. Schaefer NG, Taverna C, Strobel K, Wastl C, Kurrer M, Hany TF. Hodgkin disease: diagnostic value of FDG PET/CT after first-line therapy—is

biopsy of FDG-avid lesions still needed? Radiology 2007; 244: 257-62.
15. Freudenberg LS, Antoch G, Schutt P, Beyer T, Jentzen W, Muller SP, et al. FDG-PET/CT in re-staging of patients with lymphoma. Eur J Nucl Med Mol Imaging 2004; 31: 325-9.
16. Filmont JE, Yap CS, Ko F, Vranjesevic D, Quon A, Margolis DJ, et al. Conventional imaging and 2-deoxy-2-[(18)F]fluoro-D-glucose positron emission tomography for predicting the clinical outcome of patients with previously treated Hodgkin's disease. Mol Imaging Biol 2004; 6: 47-54.
17. Reinhardt MJ, Herkel C, Altehoefer C, Finke J, Moser E. Computed tomography and 18F-FDG positron emission tomography for therapy control of Hodgkin's and non-Hodgkin's lymphoma patients: when do we really need FDG-PET? Ann Oncol 2005; 16: 1524-9.
18. Mikosch P, Gallowitsch HJ, Zinke-Cerwenka W, Heinisch M, Pipam W, Eibl M, et al. Accuracy of whole-body 18F-FDP-PET for restaging malignant lymphoma. Acta Med Austriaca 2003; 30: 41-7.
19. Cerci JJ, Trindade E, Pracchia LF, Pitella FA, Linardi CC, Soares J Jr, et al. Cost effectiveness of positron emission tomography in patients with Hodgkin's lymphoma in unconfirmed complete remission or partial remission after first-line therapy. J Clin Oncol 2010; 28: 1415-21.
20. Brice P, Rain JD, Frija J, Miaux Y, Marolleau JP, Tredaniel J, et al. Residual mediastinal mass in malignant lymphoma: value of magnetic resonance imaging and gallium scan. Nouv Rev Fr Hematol 1993; 35: 457-61.
21. Hueltenschmidt B, Sautter-Bihl ML, Lang O, Maul FD, Fischer J, Mergenthaler HG, et al. Whole body positron emission tomography in the treatment of Hodgkin disease. Cancer 2001; 91: 302-10.
22. Rigacci L, Castagnoli A, Dini C, Carpaneto A, Matteini M, Alterini R, et al. 18FDG-positron emission tomography in post treatment evaluation of residual mass in Hodgkin's lymphoma: long-term results. Oncol Rep 2005; 14: 1209-14.
23. Talavera Rubio MP, Garcia Vicente AM, Dominguez FE, Calle PC, Poblete G, V, Hernandez RB, et al. PET-CT with intravenous contrast in the evaluation of patients with lymphoma. Contribution to diagnostic indications. Rev Esp Med Nucl 2009; 28: 235-41.

สมรรถนะในการวินิจฉัยผู้ป่วยมะเร็งต่อมน้ำเหลืองหลังการรักษาเมื่อเปรียบเทียบการตรวจ ^{18}F-FDG PET/CT กับการตรวจ CT

สุนันทา เชี่ยววิทย์, กุลธร เทพมงคล, กฤตยา อุบลนุช, จุฬาภรณ์ พูลเอี่ยม, นพรัตน์ พงษ์สวัสดิ์, พิพัฒน์ เชี่ยววิทย์

วัตถุประสงค์: เป็นการศึกษาย้อนหลังผู้ป่วยมะเร็งต่อมน้ำเหลืองหลังการรักษาเปรียบเทียบการตรวจ ^{18}F-FDG PET/CT กับการตรวจ CT โดยการวิเคราะห์ความถูกต้องในการวินิจฉัยจำแนกเป็น จำนวนการตรวจ จำนวนผู้ป่วย ชนิดของมะเร็งต่อมน้ำเหลืองที่พบบ่อย เช่น มะเร็งต่อมน้ำเหลือง non-Hodgkin ชนิด DLBCL มะเร็งต่อมน้ำเหลืองชนิด Hodgkin และข้อบ่งชี้การตรวจหลังการรักษาที่สงสัยว่าเป็นมะเร็งกลับเป็นซ้ำ หรือ หลังการรักษาภายในเวลา 2 เดือน เพื่อประเมินมะเร็งต่อมน้ำเหลืองที่เหลืออยู่หลังการรักษา

วัสดุและวิธีการ: การศึกษาผู้ป่วยมะเร็งต่อมน้ำเหลืองหลังการรักษา 67 ราย ผู้ป่วยมะเร็งต่อมน้ำเหลือง 6 ราย ไม่ได้นำมาศึกษาเนื่องจากไม่พบรายงานทางการแพทย์ เหลือผู้ป่วยมะเร็งต่อมน้ำเหลือง 61 ราย ที่นำมาศึกษา

ผลการศึกษา: ผู้ป่วยมะเร็งต่อมน้ำเหลืองชนิด Hodgkin หรือ non-Hodgkin 61 ราย เป็นเพศชาย 29 ราย เพศหญิง 32 ราย อายุเฉลี่ย 46.6±17.7 ปี ช่วงอายุ 8-75 ปี ได้รับการตรวจ ^{18}F-FDG PET/CT 77 การตรวจ ข้อบ่งชี้หลังการรักษาสงสัยว่าเป็นมะเร็งกลับเป็นซ้ำ 41 การตรวจ หรือ หลังการรักษาภายในเวลา 2 เดือน 36 การตรวจ พบว่าการตรวจ ^{18}F-FDG PET/CT มีความจำเพาะดีกว่าการตรวจ CT อย่างมีนัยสำคัญทางสถิติ และมีความแม่นยำสูงเล็กน้อยอย่างไม่มีนัยสำคัญทางสถิติในการศึกษาที่จำแนกตามการตรวจ ผู้ป่วยมะเร็งต่อมน้ำเหลือง non-Hodgkin ชนิด DLBCL และผู้ป่วยมะเร็งต่อมน้ำเหลืองที่ได้ตรวจ ^{18}F-FDG PET/CT ภายใน 2 เดือน หลังการรักษาด้วยเคมีบำบัด และการตรวจ ^{18}F-FDG PET/CT มีค่าความจำเพาะ ค่า PPV และค่าความแม่นยำสูงกว่าการตรวจ CT อย่างไม่มีนัยสำคัญทางสถิติในผู้ป่วยมะเร็งต่อมน้ำเหลืองชนิด Hodgkin และผู้ป่วยมะเร็งต่อมน้ำเหลืองที่ได้ตรวจ ^{18}F-FDG PET/CT หลังรักษาสงสัยว่ามีมะเร็งกลับเป็นซ้ำ ค่าความไวของการตรวจ CT ในการศึกษานี้มีค่าสูง เนื่องจากผู้ป่วยที่นำมาศึกษาเป็นผู้ป่วยที่พบมีก้อนเหลืออยู่ภายหลังการรักษา ดังนั้นค่าความไวของการตรวจ ^{18}F-FDG PET/CT จึงมีค่าความไวน้อยกว่าการตรวจ CT อย่างไม่มีนัยสำคัญทางสถิติ

สรุป: การตรวจ ^{18}F-FDG PET/CT มีความถูกต้องในการวินิจฉัยมะเร็งกลับเป็นซ้ำดีกว่าการตรวจ CT ในผู้ป่วยมะเร็งต่อมน้ำเหลือง non-Hodgkin ชนิด DLBCL และผู้ป่วยมะเร็งต่อมน้ำเหลืองที่ได้ตรวจ ^{18}F-FDG PET/CT ภายใน 2 เดือน หลังการรักษาด้วยเคมีบำบัด