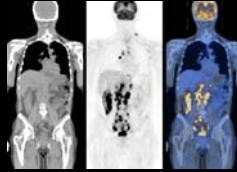


PET/CT and Lung Cancer

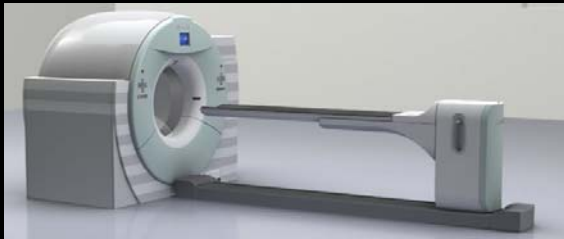


Martin Allen-Auerbach, MD
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Overview

- What is PET/CT
- What to expect if you were a patient coming to our clinic
- Notes on Radiation exposure
- PET/CT for Lung Cancer
 - Staging
 - Surveillance
 - Treatment Monitoring

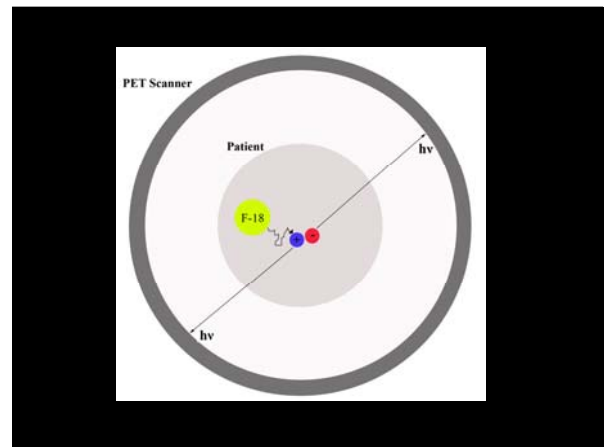
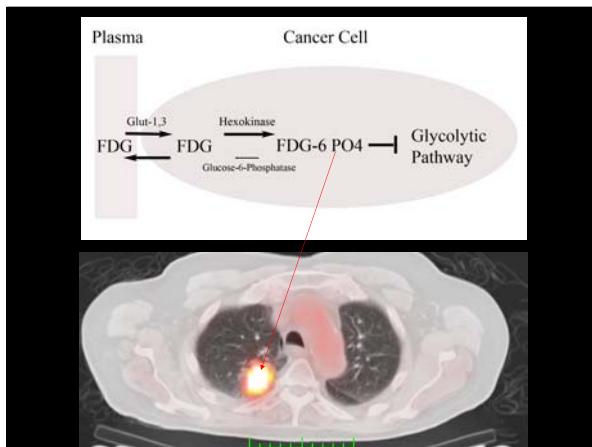
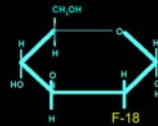
What is PET/CT?



The tracer: FDG



- FDG is an accurate tracer for evaluating metabolism of most cancers.
- FDG uptake can occur in non-cancerous conditions such as infection or inflammation.
- FDG does not have any side effects nor does it cause allergic reactions



2-[F-18]Fluoro-2-Deoxy-D-Glucose (FDG)

511 keV photon
 $E = mc^2$
 511 keV photon
 180°
 UCLA

SUV: Standardized Uptake Value

$$SUV = \frac{c(t)}{D/\text{body weight}}$$

c (t) activity concentration in the tissue
(D) injected dose

Common Errors affecting Measurement of SUVs

Error	Effect on tumor SUV
Blood glucose levels	Lower values with increasing blood glucose levels
Region-of-interest definition	Lower mean uptake for larger regions of interest; larger random errors for small regions of interest
Paravenous ¹⁸ F-FDG injection, residual activity in syringe	Incorrectly low SUV
No decay correction of injected activity	Incorrectly low SUV
Incorrect cross-calibration of scanner and dose calibrator	Incorrectly low or high SUV, depending on error of calibration factor
Variable uptake period (time between injection and imaging)	Higher SUV with longer uptake period

Weber, W.A., J Nucl Med, 2005, 46(6): p. 983-95.
 You et al. J Nucl Med, 2005 Feb;46(2):283-91
 Ditzendorf et al J Nucl Med, 2003 May;44(5):732-8

(IV and PO contrast do not affect SUV significantly)

Standardized Uptake Value (SUV)

Brain ~ 8-10
 Mediastinal Blood Pool ~2
 Malignancy >2-3
 Myocardium ~ 2-7
 Liver ~2-3
 Urine ~15-50
 Soft Tissue ~1

In the Clinic...

UCLA AHMANSON BIOLOGICAL IMAGING CENTER

Welcome to the
 UCLA Ahmanson
 Biological Imaging Center
 Nuclear Medicine Division

How to prepare for a PET/CT

- On the day of the scan take your regularly prescribed medications with water only.
- Do not eat or drink anything except water for 4 to 6 hours before the scan.
- Refrain from heavy exercise for 12 hours prior to the scan.
- Drink at least two glasses of water one hour before the scan

What to expect when you come to the Nuclear Medicine Clinic

- Your blood sugar will be checked
 - An IV catheter will be placed
 - FDG will be injected
 - You might be asked to drink oral contrast
 - You will rest comfortably for ~45 minutes
 - You will receive IV contrast
 - CT images will be obtained first (less than 1 minute)
 - PET images will be obtained (about 25 minutes)
- You should be in and out of the clinic in less than 2 hours.

Does the PET/CT Scan have Side Effects?

The PET component

- IV placement
- Claustrophobia
- FDG has no side effects

The CT Component

- IV contrast can cause an allergic response; cautious use in patients with kidney problems
- Oral contrast can cause abdominal discomfort

Frequent Patient Concerns after PET/CT

- Am I radioactive? **No, not dangerous**
- Can I be around children or pregnant women? **Yes**
- Can I eat anything I want? **Yes (and you are encouraged to drink more than usual)**

Radiation Exposure

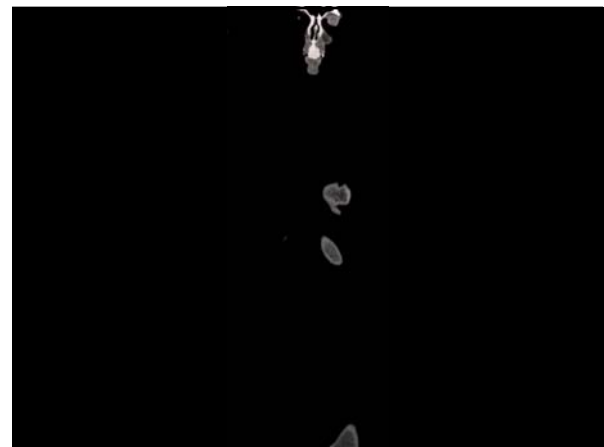
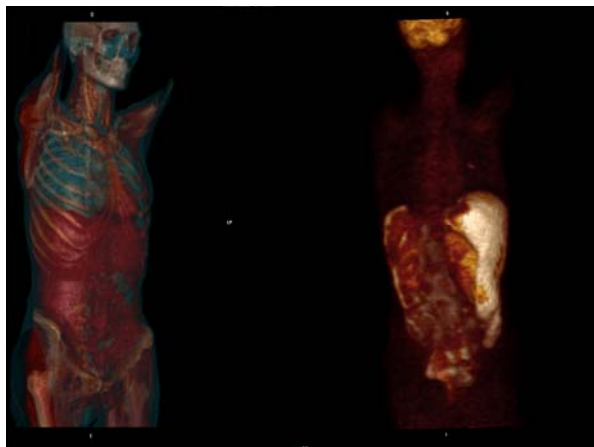
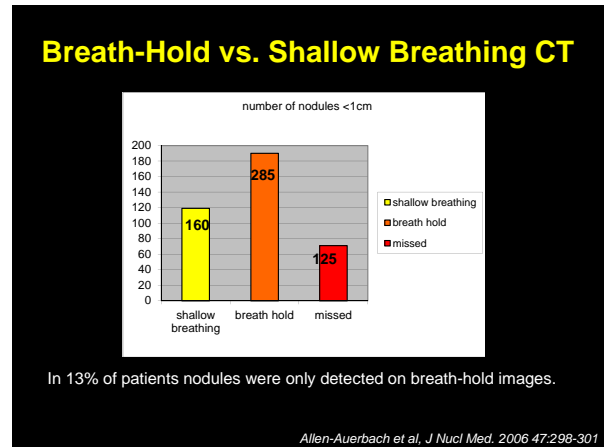
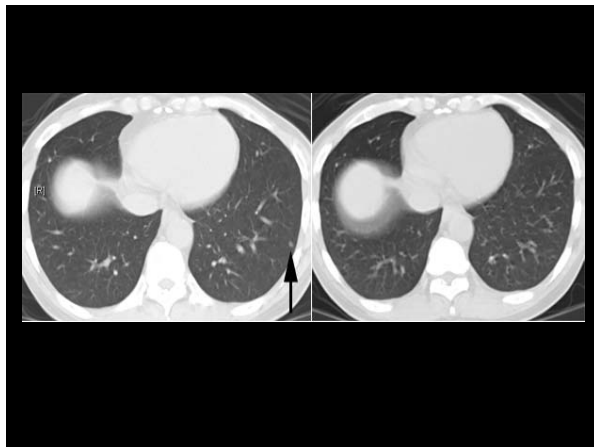
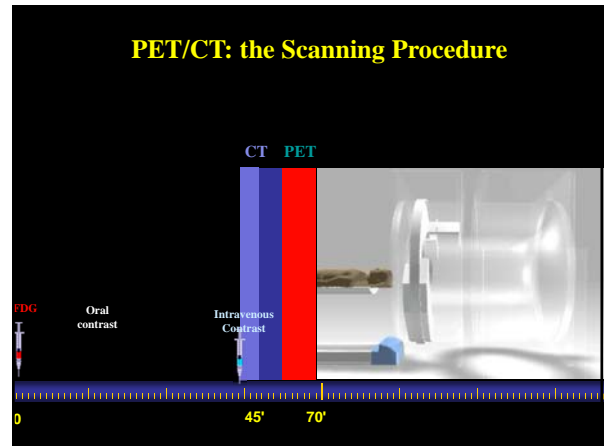
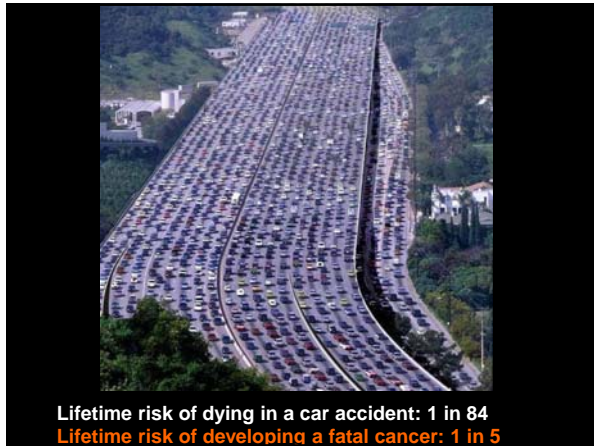


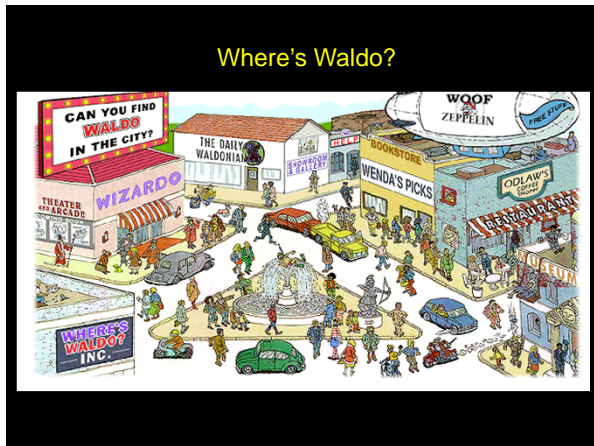
Relative Risk of developing a fatal cancer from Radiation (1PET/CT ~3 rem)

DOSE	RISK
25 rem	1 in 100
10 rem	1 in 250
1 rem	1 in 2500
0.1 rem	1 in 25000

Annual dose limit for radiation workers: 5 rem

Annual background radiation: 0.72 rem





PET/CT for Staging of Lung Cancer

TNM staging system for lung cancer (7th edition)

Primary tumor (T)

T1a Tumor ≤ 1 cm diameter, surrounded by lung or visceral pleura, without invasion more proximal than lobar bronchus

T1b Tumor ≤ 1 cm in diameter

T1c Tumor ≤ 1 cm but ≥ 0.5 cm in diameter

T2 Tumor ≥ 1 cm but ≤ 5 cm, or at least with any of the following features:

- Involves main bronchus, ≥ 1 cm distal to carina
- Involves visceral pleura
- Associated with atelectasis or obstructive pneumonia that extends to the hilar region but does not involve the entire lung

T2a Tumor ≥ 1 cm but ≤ 3 cm

T2b Tumor ≥ 3 cm but ≤ 5 cm

T3 Tumor ≥ 1 cm but any of the following:

- Invades any of the following: chest wall, diaphragm, phrenic nerve, mediastinal pleura, parietal pericardium, vertebral body, ≥ 1 cm from the central sulcus of the heart
- Involves or obstructs proximal airway of the same lung
- Involves lymph node(s) in the same lung

T4 Tumor of any size that meets the mediastinum, heart, great vessels, trachea, esophagus, vertebral body, vertebral body, carina, or with separate tumor nodule(s) in a different ipsilateral lobe

Regional lymph nodes (N)

N0 No regional lymph node metastases

N1 Metastases in ipsilateral peribronchovascular and/or ipsilateral hilar lymph nodes and ipsilateral mediastinal nodes, including ipsilateral bronchopulmonary lymph nodes

N2 Metastases in ipsilateral mediastinal and/or subcarinal lymph node(s)

N3 Metastases in contralateral mediastinal, contralateral hilar, ipsilateral or contralateral subcarinal, or ipsilateral bronchopulmonary lymph node(s)

Distant metastases (M)

M0 No distant metastases

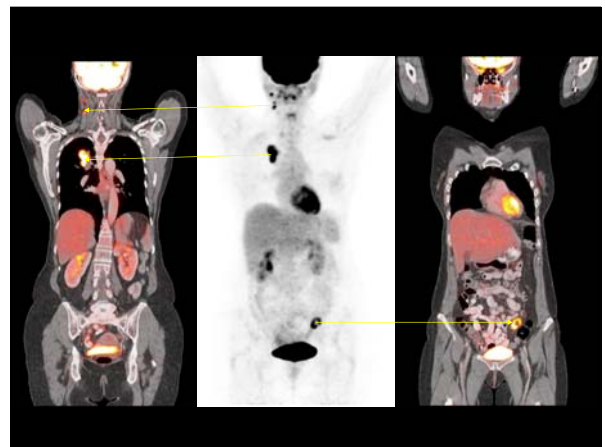
M1a Ipsilateral metastases

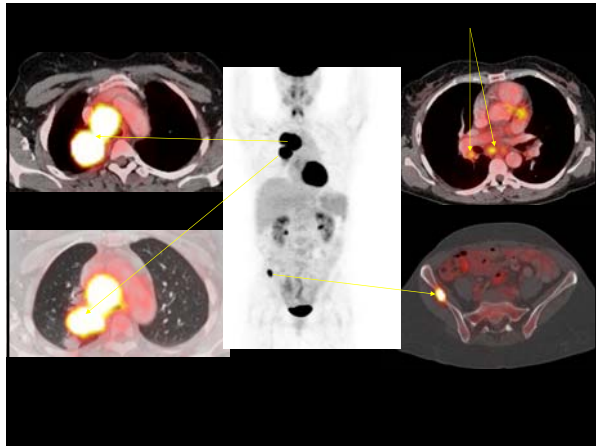
M1b Ipsilateral metastases (in a contralateral lobe, same with pleural nodules or malignant pleural) or contralateral ipsilateral ipsilateral metastases (in contralateral organ)

Stage groupings

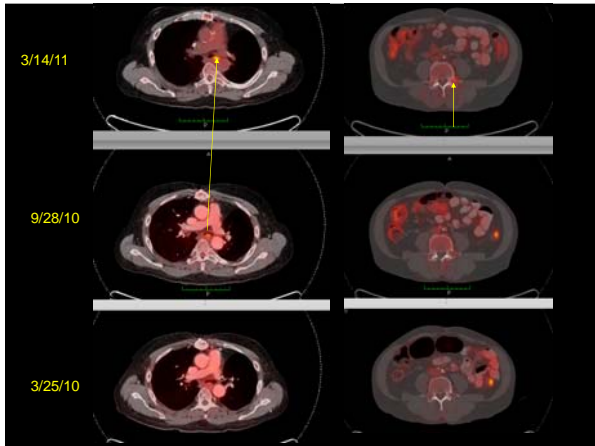
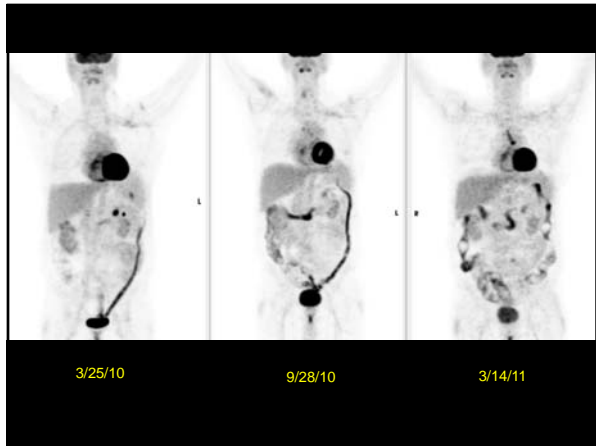
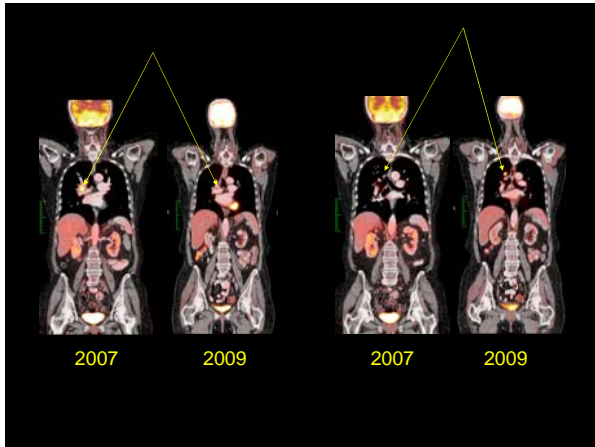
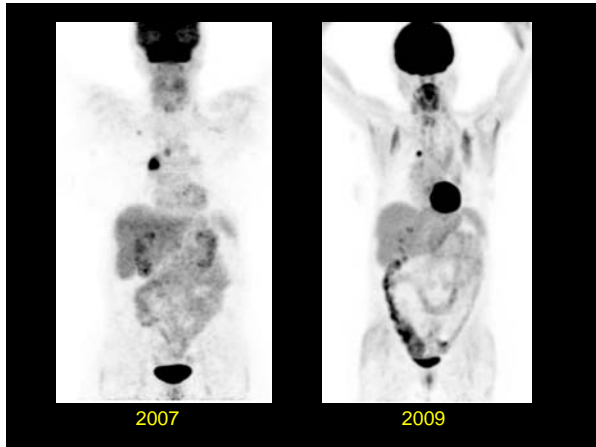
Stage	T1a-T1b	N0	M0
IA	T1a	N0	M0
IB	T1b	N0	M0
IIA	T1a,T1a,T1b	N1	M0
IIB	T1c	N1	M0
IIIA	T2a	N1	M0
IIIB	T2b,T2c	N1	M0
IIIA	T2a,T2a,T2a,T2b	N2	M0
IIIB	T2b	N2	M0
IIIC	T2c	N2	M0
IIIA	T3	N0,N1	M0
IIIB	T3	N2	M0
IIIC	T3	N3	M0
IIIA	T4	N0	M0
IIIB	T4	N1	M0
IIIC	T4	N2,N3	M0
IIIA	M1a	M0	M1a
IIIB	M1b	M0	M1b
IIIC	M1c	M0	M1c

Adapted from Goldström, C, Crowley, J, Chinnery, A, et al., The 7th Edition Lung Cancer Staging Project: Rationale for the Revision of the 6th Edition Stage Groups in the forthcoming (pending) edition of the 7th Edition of the TNM Classification of Malignant Tumors (7th Edition, 2009), p. 706.





PET/CT for Detection of Recurrence

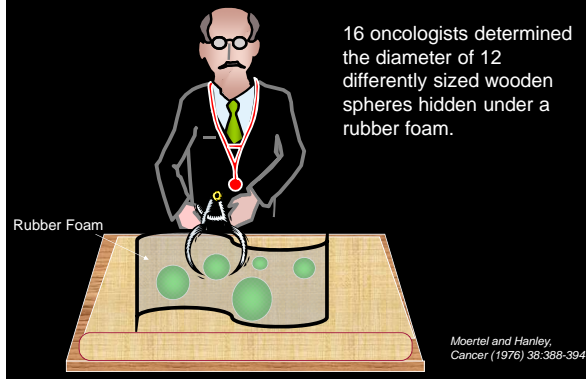


PET/CT for Treatment Monitoring

Why is Treatment Monitoring important?

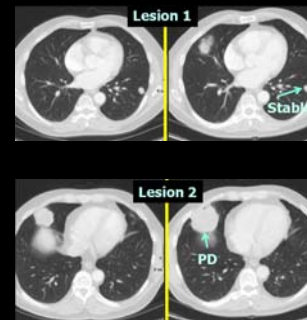
- Some patients benefit from a particular therapy whereas others (despite what seems to look like the same type of cancer) do not.
- Current therapies can have a lot of side effects. Doctors want to know as early as possible whether a treatment is working.
- The definitive proof of whether a therapy is working is if a patient feels better and lives longer.
- Looking at the cancer with scans is generally used to measure the effects of a treatment earlier.
- Current response assessment is based primarily on changes in tumor size as measured by CT (RECIST).

History of Response Criteria



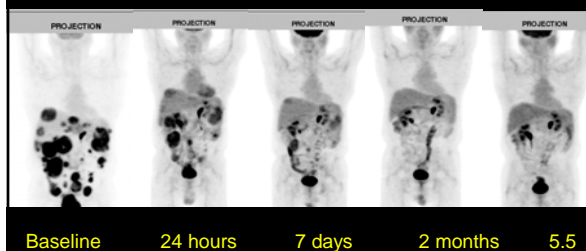
RECIST

Response Evaluation Criteria in Solid Tumors



European Journal of Cancer, January 2009

Treatment affects Metabolism of the Cancer before Changes in Size are seen



Two different Patients each 2 weeks after the start of Treatment



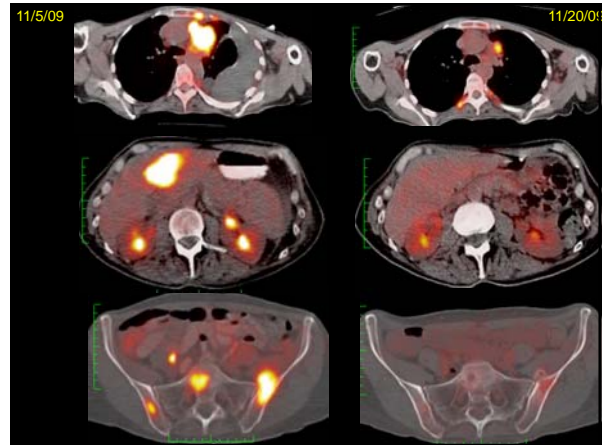
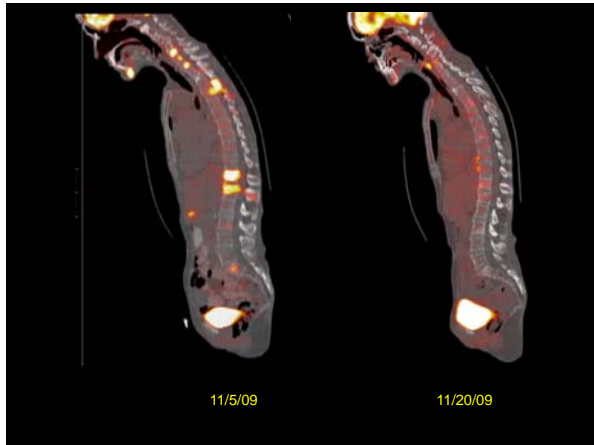
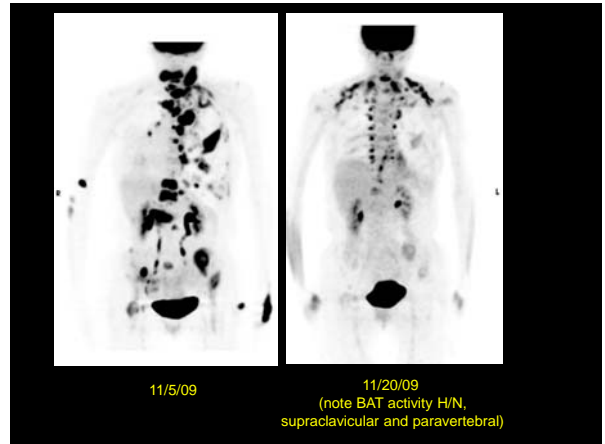
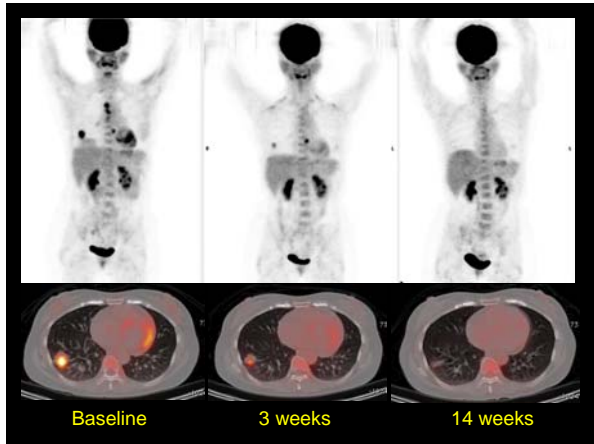


TABLE 1. Summary of Studies Evaluating the Utility of ¹⁸F-FDG PET for Therapeutic Response Assessment in NSCLC

NSCLC stage	Study	Year	No. of patients	Criteria for response on PET	Outcome measure	Design	Hazard ratio*	P
IIIA	Vansteenkiste et al. (51)	1998	15	50% decrease in SUV	Overall survival	Prospective	NR	0.03
I-III	MacManus et al. (27)	2003	73	CMR	Overall survival	Prospective	0.24	0.0004
IIIB-IV	Weber et al. (56)	2003	57	20% decrease in SUV	Overall survival	Prospective	NR	0.005
IIIB-III	Helwig et al. (47)	2004	47	SUV _{max} < 4	Overall survival	Prospective	NR	<0.001
IIIA	Howe et al. (57)	2005	47	MR _{FDG} < 0.13 µmol/mL/min	Overall survival	Prospective	0.33	0.0003
II	Pottgen et al. (38)	2006	50	50% decrease in SUV	Time to extracerebral progression	Retrospective	NR	<0.005
III	Eschmann et al. (53)	2007	70	CMR or 80% decrease in SUV	Overall survival	Prospective	NR	0.005
IB-IV	de Garcia-Oca et al. (55)	2007	51	MR _{FDG} > 47%	Overall survival	Prospective	NR	0.017
IIIB-IV	Nahmias et al. (40)	2007	16	35% decrease in SUV	Overall survival	Prospective	NR	0.016
IIIA	Dooms et al. (46)	2008	30	Decrease in SUV at wk 1-3 and >60% decrease in SUV in primary tumor	Overall survival	Retrospective	NR	0.002
IIIA-III	Decoster et al. (58)	2008	31	CMR	Overall survival	Retrospective	NR	0.004
IB-III	Tanneyanov et al. (59)	2008	89	CMR or PMR	Overall survival	Prospective	NR	NS

*Hazard ratio for patients showing response on PET vs. those showing no response on PET.
 NR = not reported; MR_{FDG} = rate of glucose metabolism; MLN = mediastinal lymph node; NS = not significant.

Rodney J. Hicks, *Journal of Nuclear Medicine*, 2009

What is missing?

- A decrease in FDG uptake on a PET scan likely means that the cancer is responding to the treatment.
- There have been many PET studies, but the definition of a response and how the scans were done have been quite variable.
- As of now there is no agreement of **when** treatment monitoring should be performed or **how much** FDG uptake has to go down to call it a good response to treatment.
- Ongoing trials are trying to answer these questions.

Summary

- FDG PET/CT is a safe test
- PET/CT is useful for Staging of Lung Cancer
- PET/CT is useful for Detection of Recurrence
- PET/CT is useful for Treatment Monitoring

