FDG-PET/CT in Lymphoma
3rd IPET Meeting, Vienna, October 2015

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Lymphoma – Clinical Data & Challenges

- Broad spectrum, heterogeneous group of diseases: >50 subtypes
- 8% of all malignancies; 6th most common malignancy in the US
- Multifocal disease

Important & common challenges:

- At diagnosis:
  - Usual nodal involvement: Inaccurate LN size-based assessment
  - Unusual nodal & extranodal involvement
- Multiple treatment options
- Response to treatment – cure rate:
  - >85% for HL; 70% for NHL (as of 2008)
- Match treatment & cure rate while considering:
  - Acute and long-term toxicities
- Pitfalls:
  - Treatment-induced inflammatory conditions
  - Residual masses 40-80%
Lymphoma – Clinical Challenges

It is important to identify

• Low-risk patients: with the aim to reduced treatment-related toxicity (& long-term adverse effects) while maintaining favorable outcomes

• Poor-risk/progressive disease/relapse: aiming to improve survival with more intense therapy

Individualized management strategy

• Prior to therapy using well defined risk categories (staging & prognostic factors)

• Early during therapy - developing predictive factors
Hodgkin Lymphoma (HL)
12% of all lymphomas

**Histological subtypes**
Classical HL 95%
- Nodular sclerosing 70%
- Mixed cellularity 30%
- Lymphocyte rich 5%
- Lymphocyte depleted

Nodular lymphocyte predominant 5%

**IPS (International Prognostic Score)**
- Stage (4), sex (M), age (>45)
- Hb, WBC (lymphocyte count), albumin

**Prognostic systems:**
- Symptoms & disease bulk
  fever, night sweats, weight loss
  A (absence)/B (presence)

**Staging (Ann Arbor)**
- I: single LN / extranodal site
- II: ≥2 LNs/extranodal (IIE) on same side of diaphragm
- III: LNs on both sides of diaphragm ± spleen (IIIS) or extranodal (IIIE) or IIISE
- IV: diffuse/disseminated extranodal ±LNs (incl. bone marrow)

- **Early stage** (favorable: I-II; unfavorable: I-II & bulky, B symptoms, no. sites & elevated ESR)
  Aim for cure: >90%
- **Advanced stage**: III-IV
  Aim for cure: 60-90%
Non-Hodgkin Lymphoma (NHL)

**Histology**

- 7th leading new malignancy
- 3% of cancer death
- Incidence: increase (AIDS-related)

**B-cell**

- NHL 80-85%
  - R-CHOP ± radiotherapy
  - Aim for cure: 20-40% relapse rate
- Indolent (mainly follicular) 15%
  - Aim for cure: 20-60% 10 y DFS

**T-cell & NK-cell: 15-20%**

**IPI (International Prognostication Index):**

- age, performance status, LDH, extranodal, stage

**FLIPI (for follicular NHL)/FLIPI2**

**Staging (Ann Arbor/St. Jude)**

- **I:**
  - single nodal/extranodal
- **II:**
  - single extranodal with regional nodal
  - ≥2 LNs same site of diaphragm
  - Primary GIT ± mesenteric LNs
- **III:**
  - ≥2 nodal/extranodal opposite sides of diaphragm
  - Extensive primary abdominal NHL
  - Paraspinal/epidural NHL ± other sites
- **IV:**
  - any of the above + CNS/bone marrow involvement
FDG-Imaging in Lymphoma
Lecture Objectives

The role of FDG-PET/CT
• Pretreatment (diagnosis & staging)
  • Avidity
  • Extent of disease
  • Patterns of nodal & extranodal lymphoma
• Impact on clinical management
  • Monitoring response at completion of treatment
  • [Early] during treatment - the “Interim” study
  • Surveillance and diagnosis of relapse
• Pitfalls in FDG assessment of lymphoma

Metabolic & functional assessment with other tracers
Assessment of Lymphoma
Non-invasive Diagnostic (Imaging) Tools

- **CT** – [previous] main modality
  - LNs: enlarged, homogenous density
  - SLL/CLL: increased no. of small LNs
- **MRI & US** – complementary tests
  - US: LNs: enlarged, homogenous echotexture
  - MR: primary modality for lymphoma of bone & CNS
- **$^{67}$Ga** – previous the only functional modality
- **FDG-PET/CT** – present single-step modality for lymphoma viability & anatomic abnormalities
FDG-Imaging of Lymphoma
Specific Issues in Acquisition Protocols

Time from treatment
• >10d from last chemo
• 2 weeks after gCSF
• 3 months after radiotherapy

Need for contrast-enhanced CT?
• PET/low-doseCT >ceCT stand-alone
• Routine: ceCT at baseline prior to PET/CT
• ceCT should be performed when:
  • PET/CT is the 1st test performed (mainly in patients who will receive radiotherapy)
  • for patients in clinical trials
FDG Imaging in Lymphoma
Clinical Indications

• Pre-treatment Staging
• Assessment of bone marrow involvement (HL & DLBC-NHL)
• Radiotherapy planning (HL & DLBC-NHL)
• Biopsy guiding in suspected transformation
• Response assessment
  – During treatment [interim] (HL & DLBC-NHL)
  – End-of-treatment (HL, DLBC-NHL & follicular)
• Diagnosis/Restaging of relapse
### FDG-Imaging of Lymphoma Pre-treatment Diagnosis

FDG Avidity of Lymphomas Based on the WHO Classification (702 patients)

*Weiler-Sagie et al, J Nucl Med, 2010*

<table>
<thead>
<tr>
<th>Histology</th>
<th>n</th>
<th>FDG-avid</th>
<th>Negative</th>
<th>% FDG-avidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>702</td>
<td>659</td>
<td>43</td>
<td>94</td>
</tr>
<tr>
<td>NHL B-cell</td>
<td>440</td>
<td>404</td>
<td>37</td>
<td>92</td>
</tr>
<tr>
<td>NHL T-cell</td>
<td>40</td>
<td>34</td>
<td>6</td>
<td>85</td>
</tr>
<tr>
<td>Hodgkin</td>
<td>222</td>
<td>222</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>
Non-FDG-Avid **NHL** (43/702 patients, 6%)  
**Histology-Based Analysis**  
*Weiler-Sagie et al, J Nucl Med, 2010*

<table>
<thead>
<tr>
<th>Histology</th>
<th>Non-avid/All</th>
<th>% FDG-avidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutaneous T-cell</td>
<td>4/7</td>
<td>43</td>
</tr>
<tr>
<td>Extranodal MZL (MALT)</td>
<td>20/43</td>
<td>53</td>
</tr>
<tr>
<td>Small lymphocytic</td>
<td>5/29</td>
<td>83</td>
</tr>
<tr>
<td>Peripheral T-cell</td>
<td>1/10</td>
<td>90</td>
</tr>
<tr>
<td>Follicular B-cell</td>
<td>7/132</td>
<td>95</td>
</tr>
<tr>
<td>DLCL B-cell</td>
<td>5/200</td>
<td>98</td>
</tr>
<tr>
<td>Enteropathy-type T cell</td>
<td>1/3</td>
<td></td>
</tr>
</tbody>
</table>

**100% FDG Avidity:** Burkitt, Anaplastic large T-cell, Mantle, Angioimmunoblastic, T-Lymphoblastic, Extranodal NK/T, B-lymphoblastic, nodal MZL
# Non-FDG-avid Lymphoma

**Location- & Clinical Characteristics Based Analysis**

*Weiler-Sagie et al, J Nucl Med, 2010*

<table>
<thead>
<tr>
<th>Anatomical Location</th>
<th>Non-avid/All</th>
<th>% FDG-avidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Cutaneous (DLCL, FL, MALT, T-cell)</td>
<td>14/25</td>
<td>44</td>
</tr>
<tr>
<td>Primary Gastric (All MALT)</td>
<td>12/45</td>
<td>73</td>
</tr>
<tr>
<td>Nodal sites only (All SLL)</td>
<td>5/311</td>
<td>98</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clinical Characteristics</th>
<th>Non-avid/All</th>
<th>% FDG-avidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggressive (HL, DLCL, Mantle, Burkitt)</td>
<td>7/260</td>
<td>97</td>
</tr>
<tr>
<td>Indolent (eg. Follicular, MALT, SLL)</td>
<td>36/220</td>
<td>84</td>
</tr>
</tbody>
</table>

**Intensity of FDG avidity** (*Schroder et al, JCO 2005*)
- aggressive > indolent
- SUVmax threshold ≥10, sensitivity 71%, specificity 81%
Non-FDG-avidity of lymphoma

Weiler-Sagie et al, J Nucl Med, 2010

- FDG non-avid - 6% of a large patient group (n=702) including most histological subtypes of lymphoma.

- Higher rate of non-FDG-avidity:
  - MALT (47%, all extranodal)
  - SLL (17%, single subtype with non-avid nodal-only disease)

- Lymphoma of skin: less FDG-avid (56%), regardless of histology

- Indolent (16%) > aggressive (6%)
FDG imaging at Staging of Lymphoma

FDG imaging is incorporated into staging of FDG-avid lymphomas
Exceptions: extranodal marginal zone; SLL/CLL, mycosis fungoides

• Upstaging > downstaging; up to 20%
• FDG > CT, mainly for extranodal sites (BM, bone, spleen, liver)

Incremental value for:
• Planning stage-dependent therapy:
  • define patients to benefit from radiation and/or chemo
  • planning of radiotherapy

Change in management/therapy: 10-15% patients
• Response assessment is more accurate in 19-34% cases in the
  presence of a base-line study
Performance of FDG Imaging in Lymphoma at Staging

FDG imaging performance at staging:
• Patient-based: sensitivity: 91%
• Lesion-based: 96%

Comparison to ceCT: superior specificity (nodal & extranodal)
• FDG sensitivity 86% specificity 100%
• CT 88% 88%

Kwee et al, Blood 2008, and many more studies
FDG Imaging in Lymphoma at Staging

HL - Upstaging

Additional previously unknown para-aortic LN disease
Based on PET/CT this patient has Stage 4 disease.
FDG-PET/CT and Bone Marrow Biopsy Diagnosis of Bone Marrow Involvement in HL (337 patients)

Weiler-Sagie et al, EJNMMI 2014

337 patients (incl. 82 children)
- BM Biopsy (+): 9 pts (3%)
- FDG-PET/CT (+) BM involvement: 75 pts (16%)

FDG patterns of BM involvement
- 61% ≥ 3 FDG (+) foci
- 88% ≥ 1 focus in pelvis/spine
- 83% CT (-) > CT (+) sites

<table>
<thead>
<tr>
<th>Study</th>
<th>No. pts</th>
<th>FDG (+) BM</th>
<th>BMB (+)</th>
<th>False Negative FDG</th>
<th>FDG (+) BM Upstage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weiler-Sagie (2014)</td>
<td>475</td>
<td>16%</td>
<td>3%</td>
<td>3%</td>
<td>53/475 (11%)</td>
</tr>
<tr>
<td>El-Galaly (2012)</td>
<td>454</td>
<td>18%</td>
<td>6%</td>
<td>5%</td>
<td>-</td>
</tr>
<tr>
<td>Muzahir (2012)</td>
<td>122</td>
<td>21%</td>
<td>9%</td>
<td>2%</td>
<td>9/122 (7%)</td>
</tr>
<tr>
<td>Purz (2011)</td>
<td>175</td>
<td>26%</td>
<td>4%</td>
<td>0</td>
<td>20/175 (11%)</td>
</tr>
<tr>
<td>Pelosi (2011)</td>
<td>82</td>
<td>16%</td>
<td>7%</td>
<td>5%</td>
<td>-</td>
</tr>
</tbody>
</table>
FDG-Imaging of Lymphoma
Performance for Diagnosis of Bone Marrow Involvement

- Sensitivity 51%; Specificity 91%

**HL & aggressive NHL**
- Higher sensitivity:
- 2\text{nd} BMB at FDG+ site will be BMB+ in 50% pts

- FN in small volume disease (<10%)
- FDG+BM: Prognostic value – predictor of PFS

**Indolent NHL:**
- Sensitivity of FDG<45%: BM biopsy remains gold standard
- Diffuse uptake is more common
# FDG Imaging in Gastric Lymphoma

**Incidence, Patterns & Intensity of FDG Uptake**

*Radan et al, EJNMMI, 2008*

<table>
<thead>
<tr>
<th></th>
<th>Total (n=62)</th>
<th>MALT</th>
<th>DLCL-NHL</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDG avidity</td>
<td>55 (89%)</td>
<td>17 (76%)</td>
<td>38 (100%)</td>
</tr>
<tr>
<td>Intensity: visual (&gt;liver uptake)</td>
<td>51 (93%)</td>
<td>14 (82%)</td>
<td>37 (97%)</td>
</tr>
<tr>
<td>Intensity: SUVmax</td>
<td>15.3 ± 11.7</td>
<td>5.4±2.9</td>
<td>19.73±11.5</td>
</tr>
<tr>
<td>Pattern – Diffuse</td>
<td>33 (60%)</td>
<td>10 (59%)</td>
<td>20 (53%)</td>
</tr>
</tbody>
</table>

Extragastric sites
61% - only DLCL

![FDG Imaging Examples](image-url)
FDG Imaging in Cutaneous Lymphoma

- 2% of all NHLs; 2\textsuperscript{nd} most common extranodal NHL (after GIT)
  - T-cell: 71% (most common) – Subtypes: Mycosis fungoides 56% & Sezary syndrome
  - B-cell

**Role of FDG:**

*Scarce literature (≈225 patients with FDG)*

- Targeting biopsy in T-cell
- FDG more accurate than CT in detecting skin lesions
- Intensity of uptake correlates with histologic grade
- Treatment planning in advanced stage disease
FDG Imaging in Follicular NHL

- 2nd most common NHL, 1st most common indolent NHL
- FDG imaging at staging:
  - Sensitivity 94%
  - Large range of intensity of uptake
- FDG defines extent of FL: ~60% with apparent stage I-II disease have more advanced disease (change in treatment strategy)
- Monitoring response to treatment:
  - End-of-treatment > interim for prediction of outcome (slower response vs. HL & DLBCL)
  - Response accuracy: FDG > FLIPI & CT
- Guide for biopsy in suspected transformation
FDG Imaging in Follicular NHL

- F, 61, Follicular NHL with BM involvement
- Good response at end-of-treatment
Lymphoma Transformation

- Indolent NHL (Follicular, Mantle cell) and leukemia (mainly CLL) can develop transformation to aggressive lymphoma
- Risk for transformation: independent of stage, duration & response to treatment
- FDG for diagnosis of transformation: high sensitivity, specificity, NPV
- In patients with strong clinical suspicion FDG identifies [extra]nodal sites for confirmatory tissue sampling
SLL/CLL Transformation to DLBC-NHL

- F, 63, CLL for 11yrs, treated with steroids & chlorambucil
- Recent onset of fever

Low FDG+ neck & mediastinal LNs - CLL
SUVmax 2.70-3.45

Intense FDG+ in spleen & LNs in abdomen and plevis
SUVmax 30.9
FDG PET/CT – a Biomarker in Lymphoma for Assessment of Prognosis and Response to Treatment

- **International Harmonization Project (IHP) criteria** *Juweid, JCO 2007*
  focal/diffuse FDG+ above background

- **Deauville criteria** *Meignan et al, Leukemia Lymphoma 2009*
  grading the FDG avidity;

- **Lugano classification** *Barrington et al, JCO 2014*
  Simplifies & standardization of response assessment & reporting criteria for FDG-PET/CT at staging & interim study

- Recommendations of the **International Conference on malignant lymphoma; (ICML) criteria** *Chesson et al, JCO 2014*

  **Aim:** minimizing false positive reports during or at end-of-treatment (residual FDG uptake vs. residual disease)
Anatomic and Metabolic Visual Criteria for Response Assessment of Lymphoma

<table>
<thead>
<tr>
<th>CT</th>
<th>FDG – Deauville Score</th>
</tr>
</thead>
</table>
| Primary tool in non-FDG-avid lymphoma  
• Nodal size: threshold 1.5 cm  
• Decrease, no change or increase in size  
• Presence or absence of old/new findings | Five-point scale  
1. No uptake  
2. Uptake ≤ mediastinum  
3. Uptake > mediastinum but ≤ liver  
4. Uptake moderately > liver  
5. Uptake markedly > liver and/or new lesions  
6. (X) New areas of uptake |
Lugano Criteria for Visual Assessment of Lymphoma Response to Treatment

<table>
<thead>
<tr>
<th>CT</th>
<th>FDG-PET/CT</th>
</tr>
</thead>
</table>
| • Complete radiologic response  
  – All LNs ≤ 1.5 cm longest axis  
  – Disappearance of all findings  
• Partial remission: ≥ 50% decrease in disease burden  
• Stable disease: < 50% decrease in disease burden  
• Progressive disease:  
  – new or increased lymphadenopathy  
  – new extranodal sites | • Complete metabolic response: Deauville score 1,2,3 (± residual mass)  
• Partial metabolic response: Score 4,5 & reduced FDG uptake (& residual mass of any size)  
• No metabolic response: Score 4,5 & no change in intensity of FDG uptake  
• Progressive metabolic disease: Score 4,5 & increased FDG uptake and/or new lesions |

Deauville Score 3:  
• Complete metabolic response in clinical routine  
• Inadequate response in clinical trials
FDG Imaging of Lymphoma
Quantitative Analysis

- Need for prognostic & predictive indices
  - To define the initial tumor burden
  - To determine early and accurate response to treatment
  - To detect small group with high risk of relapse/failure
- SUVmax (usually in hottest lesion)
- \( \Delta \text{SUVmax} \) (% decrease from baseline to post-treatment)
  \( \Delta \text{SUVmax} \) (threshold of 66-70%) - indicator of good response:
  - NHL: 66% at 2 cy; 77% at 4 cy
  - HL: 71% at 2 cy
- Measures of tumor burden
  - Total metabolic tumor volume (MTV)
  - Total lesion glycolysis (TGL)
End-of-Treatment  FDG Imaging of Lymphoma
Residual Mass vs. Residual Lymphoma

Residual mass ≠ Residual tumor
• CT is an indicator of tumor mass
• FDG-PET is an indicator of viable cancer

FDG PET is more specific indicator of nature of a residual mass vs. size criteria of morphologic imaging

End-of-treatment:
• FDG has a high NPV
• Prognostic value: poor in FDG+
• FDG- & no residual mass > FDG- with residual mass
FDG Imaging at the End-of-Treatment
Good predictor of prognosis & clinical outcome

Progression free survival
FDG+ vs. FDG-

©Spaepen, JCO 2001
©De Wit, Annals Oncol 2001
FDG Imaging at End-of-Treatment

Pre-therapy

End-of-Treatment

Complete Response        Tumor Progression
Aims of [Interim] FDG Imaging During Treatment of Lymphoma

- Optimize outcome while minimizing toxicity
- Tailor individual risk & response-adapted treatment
- Provide an early surrogate endpoint to DFS or OS

Hypothesis:
Rapid reduction in FDG uptake is associated with good prognosis and can avoid unnecessary and costly treatment
Interim FDG Imaging
1. “How early? ASAP!”


• “Early” – “near the beginning ...before the usual /expected time”
• Metabolic changes precede structural (size) changes earlier during treatment
• In responders: 80-90% of the chemo effect on FDG uptake - within first 7 days of treatment

Lucignani: “Molecular and functional imaging can ...be synonymous for early and accurate answers”

• Early FDG assessment can/should be performed after 1-3 chemo cycles
Interim FDG Imaging of Lymphoma

2. How positive is a positive study?

- Avoid FNs
  - Interim study has to be performed just prior to next cycle
  - Size of residual mass on CT (threshold: 1.5cm for LNs)
- Visual assessment of intensity of FDG uptake
- Semi-quantitative (SUV measurements) challenges - variability:
  - Inter-observer
  - Parameters: time after injection; fast; blood glucose & insulin levels
- Main issue: “standardization” in/between centers

Comparing patients with same:
- Histologic type
- Treatment
- Imaging device
- Definition of positive & negative studies
- Criteria for response & comparison of studies
No negative follow-up studies
Tumor progression to LN, liver, bowel
Last FU - alive with disease
FDG-Imaging of Lymphoma during Treatment
Positive but Minimal Residual Disease Interim PET/CT

F, 57, DLCL, Stage 3B

Staging

FDG-PET/CT became negative after 21 months
Last FU: negative PET/CT & **No evidence of disease**
Achieving and duration of CR is significantly affected by rapidity of tumor regression, an index of tumor sensitivity to chemotherapy

(Armitage et al, JCO 1996)
Results of a Trial of PET-Directed Therapy for Early-Stage Hodgkin’s Lymphoma


CONCLUSIONS
The results of this study did not show the noninferiority of the strategy of no further treatment after chemotherapy with regard to progression-free survival. Nevertheless, patients in this study with early-stage Hodgkin’s lymphoma and negative PET findings after three cycles of ABVD had a very good prognosis either with or without consolidation radiotherapy. (Funded by Leukaemia and Lymphoma Research and others; RAPID ClinicalTrials.gov number, NCT00943423.)
FDG-Imaging of Lymphoma—Prognostic Value

**HL:**
- Interim FDG is an independent predictor of prognosis
- Persistent uptake in advanced HL: poor prognosis
  - Relapse rate FDG+ 27% vs. FDG- 2.3%
- “reduce if possible, intensify if needed” *(Dann et al, Blood 2007)*

**NHL:**
- Controlled reduction only in favorable young pts; no bulky
- Predictor: iPET > IPI
- Identify beneficiaries from BM transplantation

**NHL vs. HL:**
- Predictive value of FDG: HL>NHL
  - lower NPV in NHL (worse intrinsic NHL prognosis)
  - lower PPV in NHL (higher risk of FDG+ infection; addition of rituximab with FDG+ inflammatory response)

**Importance of biopsy in FDG+ studies**
FDG-PET/CT Guided Tissue Sampling

F, 22, HL, Residual mass
**Recurrence** proven by PET/CT guided biopsy
FDG-PET/CT Guided Tissue Sampling

F, 16, HL, Residual uptake
PET/CT guided biopsy – inflammatory changes
Post-therapy Surveillance (Follow Up) in Lymphoma

• Relapse rate:
  – 20-50%
  – symptomatic > asymptomatic patients
  – highest in first 3yrs after completion of treatment

• No clear correlation between [early] detection of relapse & [better] outcome

• Routine surveillance:
  – Controversial in early-stage, low-risk
  – Justified in cases with high risk for relapse

Most relapses are diagnosed at unscheduled visits prompted by symptoms or a palpable mass

©Leidtke et al, Annals of Oncology 2006
FDG-PET/CT
EARLY diagnosis of recurrent lymphoma

F, 58, aggressive NHL, CR 36 mo, routine FU

Biopsy lt. inguinal LN
Recurrent NHL
FDG Imaging in Recurrent Lymphoma

Improved Diagnosis:
• Precise localization of suspicious FDG-avid foci
• Characterization of CT lesions: malignant or benign
• Assessment of whole extent of disease

Improved Management:
• Defining the best therapeutic strategy
• Planning the therapeutic approach
• Sparing unnecessary treatment
FDG-Imaging of Lymphoma for Surveillance & Diagnosis of Relapse

• FDG detection of unsuspected relapse (HL & aggressive NHL): 10%
• Early study (2003): FDG preceded CT for detection of relapse by 9 month
• Suggested follow-up:
  – asymptomatic patients & in the presence of a residual mass: FDG for 24 mo
  – in initial aggressive lymphoma: >24 mo
FDG-Imaging of Lymphoma
Diagnosis of Relapse

- **Performance:**
  - FDG Imaging: PPV 95% NPV 83%
  - Conventional Imaging: PPV 72% NPV 67%

- **FDG:**
  - High sensitivity for detecting relapse
  - Defines extent of relapse
  - Guides tissue biopsy, decrease in sampling error

- **FDG - false positives:** important to be familiar with the specific benign uptake patterns, in particular related to treatment

Importance of integrating clinical & imaging data
FDG Imaging in Lymphoma

Pitfalls

FDG is not specific for lymphoma!
Other FDG avid processes:
- Infection
- Inflammation
- Granulomatous diseases
- Synchronous malignancies
- Physiological variants
Blood glucose levels at time of FDG injection
Recurrent Diffuse Large Cell NHL

Dec’ 2004
Before Rx
Glucose 82

Feb’ 2005
2 cycles
Glucose 326

Apr’2005
4 cycles
Glucose 137
Physiologic FDG Uptake in Thymus Hyperplasia

M, 11, Hodgkin’s, Follow up
Inverted “Y” shape in upper, anterior mediastinum
FDG uptake in thymic hyperplasia
FDG Uptake in Thymus

Jerushalmi et al, JNM 2009

- Physiologic uptake in young children unrelated to treatment
- Thymic uptake in treatment-related hyperplasia (incl. 9% young adults up to the age of 40)
- Typical shape and location (unusual location)
- After completion of Rx (duration - during Rx)
- Patterns on serial studies (no changes in size or intensity, SUV ~2.9-3.9)
Physiologic FDG Uptake in Ovulating Ovary (in Pre-menopausal Women)

Lerman et al, J Nucl Med, 2004
FDG Activity in Left Pelvis
Distorted Anatomy
Importance of detailed clinical history

Zissin et al, Br J Radiol, 2006

F, 25, Hodgkin Lymphoma, Follow up
FDG activity at the site of surgical clips
Surgically transposed ovaries
FDG Activity in Right Pelvis
Importance of clinical history & PET/CT

Amenorrhea
Early diagnosis of recurrent lymphoma in ovary

14 days after last menstruation
Ovulatory phase
Physiologic uptake in ovary
Feasibility studies with limited no. of patients

Staging:
- MRI (DWI) has slightly lower performance indices vs. FDG-PET/CT

• Interim evaluation
  - Inconclusive comparative data with PET/CT

• End-of-treatment evaluation
  - Single study with MR (15 patients) with promising results
PET Imaging of Lymphoma
Beyond FDG

$^{18}$F-FLT (fluorothymididine) – index of cell proliferation; uptake $\sim$ Ki-67 index

- Less affected by post-therapy inflammation
- ? Value in early therapy response assessment: early decrease in uptake after (R-)CHOP
- (preclinical): good predictor of PFS & overall survival

$^{18}$F-fludarabine - labeling a drug used for treatment of indolent NHL: (preclinical) uptake superior to FDG
FDG Imaging in Lymphoma
NCCN Guidelines (2014)

• FDG is recommended for initial staging and for evaluation of residual masses at the end of treatment
• Exception: CLL/SLL, mycosis fungoides, marginal zone NHL
• If the PET/CT includes a diagnostic CT no additional separate CT is required
• Deauville criteria should be used for assessing interim and end-of-treatment studies
FDG Imaging in Lymphoma

- We have to understand the unmet needs & expectations of the referring physicians
- We have to understand the specific clinical characteristics of lymphoma – a multifocal disease with high and rising response rates to known & new treatment options

- FDG-PET/CT is a powerful and accessible tool for assessment of lymphoma providing accurate and clinically useful data for diagnosis and further patient care
- It has a role in staging and assessment of response to treatment, as an early predictor of outcome during treatment and for diagnosis of relapse.
Thank you!