Optimized PET/CT protocols: how much CT is needed?

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Increasing use of PET-CT

- RIZIV survey 2010
  - 13 accredited PET centra, 7 non-accredited centra
  - 25 “RIZIV billing” systems of which 14 PET-CT
  - 42,000 PET scans in 2008 (50% RIZIV approved indications)
- Portion full CT vs low dose CT is variable
  - ERS/EANM survey 2009

Basic Principle = ALARA
As Low as Reasonably Achievable

- Justification
  - The test must be medically indicated
  - Accurate
  - No alternative test without radiation with similar accuracies available
  - (Cost-effective)
- Optimization
  - Best diagnostic image NOT most “beautiful” image

Technical Innovations in PET and CT to reduce radiation

How much CT is needed in PET/CT

Imaging in Lymphoma

- Imaging plays a central role in patient management
  - diagnosis and staging
  - treatment planning and evaluation of treatment effects
  - managing inter-current illness and complications
- Role of routine imaging procedures for surveillance is questionable
  - Relapses are diagnosed most often clinically
  - Early detection (and treatment of recurrence) does not improve OS
  - Clinical guidelines (ESMO, NCCN) do not recommend routine imaging during FU but it is often performed in daily practice
  - Legitimate concern that surveillance imaging may expose patients to unnecessary and ineffective radiation

Justification

Example: Evidence for PET or PET/CT for surveillance?
Imaging in Lymphoma

- Retrospective estimation of the cumulative radiation exposure from diagnostic and follow-up imaging in a cohort of 150 children diagnosed with a malignancy in the calendar year 2001
- Inventory of number and type of diagnostic and interventional imaging procedures performed during a 5-year period from the first diagnostic procedure
- Cumulative effective dose estimates were calculated, based on both institutional dose data and published literature

- Median cumulative Effective dose = 61 mSv
  (range <1 - 642 mSv)

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Subgroup analysis of imaging during first-line treatment in 29 lymphoma patients

- **N  Scans**
- **% Effective cum dose (mSv)**
- **%**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>N Scans</th>
<th>%</th>
<th>Effective cum dose (mSv)</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>X-ray</td>
<td>303</td>
<td>44</td>
<td>17</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>CT</td>
<td>203</td>
<td>29</td>
<td>1740</td>
<td>26</td>
</tr>
<tr>
<td>Radionuclide</td>
<td>127</td>
<td>23</td>
<td>4854</td>
<td>73</td>
</tr>
<tr>
<td>Interventional</td>
<td>27</td>
<td>4</td>
<td>59</td>
<td>&lt;0.5</td>
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<tr>
<td>Totals</td>
<td>690</td>
<td></td>
<td>6670</td>
<td></td>
</tr>
</tbody>
</table>

Indications for Imaging Procedures:
- 34% protocol required
- 66% discretionary investigations

- No clear indication in 12.5% of examinations (CT, Gallium scans >40 mSv)

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Imaging in Lymphoma

Risk-based PET surveillance
Petrausch et al (Zurich), J Annals of Oncology 2010

- Retrospective study in 134 HD and 75 DLBCL in CR/CRU after first-line therapy (2/3 PET-) with at least 1 PET/CT in FU
- Hybrid PET/CT
- HD 134 patients, 42 recurrences
  - +PET more frequent in sympt (32/51 or 63%) vs asymp (10/83 or 12%)
  - No info on FPR only PPV 98% (1 patient?), NPV 100%
- NHL 75 patients, 27 recurrences
  - +PET more frequent in sympt (23/40 or 57%) vs asymp (4/35 or 11.5%)
  - 3 false positives 1 lung cancer PPV 85%, NPV ?

Conclusions: restrict use of PET/CT to patients with a high risk of relapse

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Optimization
PET improvements
CT dose reduction strategies
How much CT is needed?

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PET technique – Historical Overview

- 1995
- 2003
- 2010

- 3 N scan
- <15 min/scan

- Sheet low PET
- 128 slice PET
AC 64-65 ring source
PET-CT (128 slice)
- 22 on FDG
AC CT based HD-TOF
Better signal to noise ratio, improved sensitivity?
Lower FDG dose, shorter scan times (5 to 15 min/WB)

High throughput (upto 25 patients/day)
Use of lower FDG doses (15 mCi ~ 7 mSv; 7 mCi ~ 5 mSv)

Dose Reduction Strategies in CT
• Omit multiple phase scanning on overlap between scans
• Eyes outside FOV for full CT

FDG dose and emission time/bedposition

<table>
<thead>
<tr>
<th>Patient weight (kg)</th>
<th>Mode</th>
<th>Type</th>
<th>Time (min)</th>
<th>Bedwidth (mm)</th>
<th>FDG dose (mCi)</th>
<th>Radiation dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-50</td>
<td>4D</td>
<td>2D</td>
<td>150</td>
<td>150</td>
<td>15</td>
<td>0.7</td>
</tr>
<tr>
<td>50-60</td>
<td>5D</td>
<td>2D</td>
<td>200</td>
<td>200</td>
<td>15</td>
<td>0.7</td>
</tr>
<tr>
<td>60-70</td>
<td>5D</td>
<td>2D</td>
<td>250</td>
<td>250</td>
<td>15</td>
<td>0.7</td>
</tr>
<tr>
<td>70-80</td>
<td>5D</td>
<td>2D</td>
<td>300</td>
<td>300</td>
<td>15</td>
<td>0.7</td>
</tr>
</tbody>
</table>

State-of-the-art CT systems

2003 – 2 slice CT
2010 – 64 slice CT

Dose reduction strategies in CT
• automated exposure control (AEC) = Tube current modulation (mA) to change X-ray intensity according to patient attenuation

Dose reductions of 20-40%
Dose reduction strategies in CT

- Adjusting the tube potential (kV) to patient size when iodine contrast enhancement is used (attenuation of iodine increases with lower kV resulting in better contrast)

How much CT is needed?
Difference in radiation exposure between different scanning protocols is attributed to CT setting!

PET-CT imaging protocols

- Low dose WB -CT + WB-PET
- CE-CT (medium-dose) + WB-PET
- Low dose WB-CT + WB-PET + CE-CT Tx-Abd

PET-CT imaging protocols

- Total radiation dose < 10 mSv
- When?
  - If full CT was already performed
  - E.g. initial staging
  - If full CT is not needed
  - E.g. FU of Lymphoma
**PET-CT imaging protocols**

**Additional Head and Neck images**

- **WB-PET** (1.5 min); CT: 30 mA
- **H&N PET** (3 min); CT: 60 mA

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**PET-CT imaging protocols**

**WB-PET with full CT**

- Radiation Dose variable and depending on CT settings
  - Define proper settings (ALARA) based on
    - Indication (FOV)
    - Size of patient (tube voltage)
    - Possibilities of scanner (iterative reconstruction software)
- When?
  - If both PET and CT need to be done (one stop shop)
    - e.g. Flu of cancer patients, radiation treatment planning

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**How much CT is needed?**

**Lymphoma Surveillance Example**

- PET/LD-CT >> ceCT
  - Hany et al, Radiology 2004
  - Lavender et al, JNM 2010
- PET/ceCT = PET/LD-CT but higher level of confidence
  - Rodriguez et al, JNM 2006
  - La Fougere, Nuklearmedicine 2008
  - Nakamoto et al, Ann Nucl Med 2010

**PET/ceCT in surveillance:**

- best protocol in selected indications

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**PET-CT imaging protocols**

**Lymphoma surveillance**

DD iliacal hot spot

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**PET-CT imaging protocols**

**WB-PET with full CT**

- Full CT before or after WB-PET
  - Pro “Before”
    - can be used for AC (artefacts contrast on PET quantification minimal)
    - Less misalignment artefacts
  - Pro “After”
    - Smaller FOV (Thorax-Abdomen), ideally decide on CT FOV after seeing WB-PET
    - More optimal CT protocol (max inspiration) but more misalignment
    - No effect on PET examination if allergic reaction on CT contrast

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**Misalignment Artifacts**
PET-CT imaging protocols
Patient Positioning

Dedicated protocols for children

FDG dose
- Two methods for dose calculation
  - Fixed dose per kg/body weight (3-7.5 MBq/kg)
  - EANM dose chart (takes into account the higher susceptibility for radiation induced cancers in younger persons)
- ALARA
  - trade off between scan time and dose

CT acquisition Protocol
- if possible with Diagnostic CT
  - One stop shop
  - Increased diagnostic confidence
  - Better PET image quality

FDG biodistribution in children
Less tissue contrast (no fat)
Dedicated PET-CT protocols for Children

“The Journal of Nuclear Medicine • Vol. 59 • No. 10 • October 2009

Dedicated PET-CT protocols for Children

“Optimal” PET-CT protocol

- Differences in radiation dose is dependent on CT protocol
  → Optimal use of CT radiation reduction tools
  → Best diagnostic image ≠ most beautiful image

- Avoid duplication!

- Optimal protocol but probably difficult to perform in routine clinical practice
  - Start with low dose CT + WB-PET
  - Decide on need/FOV of full CT after viewing PET images.