CT Protocols and CT Dose Contribution in PET/CT

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iPET 2011 – Parallel Session IIIc
Panel Discussion: Practical Aspects of CT
Introduction

Clinical Implementation of PET/CT

• Nuclear medicine imaging has changed dramatically at the end of the 90's with the introduction of multimodality imaging.

• Several advantages of adding CT-scanning to PET:
  ■ Combine functional and morphological information
  ■ Improvement of attenuation correction and anatomical localization
  ■ Enhancement of diagnostic information
  ■ Better patient throughput
  ■ Possibility for metabolic guided biopsy/resection
  ■ ...

CT protocols and CT dose contribution in PET/CT
C. Vandevoorde
Introduction

Increasing use of PET/CT

• Almost all PET equipments purchased today are PET/CT devices

<table>
<thead>
<tr>
<th>Cases reviewed</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Number of interpreting physicians</td>
<td>162</td>
</tr>
<tr>
<td>Integrated PET/CT ( n = 178 )</td>
<td></td>
</tr>
<tr>
<td>PET/CT</td>
<td>149</td>
</tr>
<tr>
<td>PET</td>
<td>29</td>
</tr>
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</table>

Coleman et al. (JNM 2010)

• Although the use of CT in NM imaging is increasing diagnostic accuracy, it also increases patient radiation doses significantly:
  - Huang et al. (Radiology 2009) – CT may contribute up to 76% of the total effective dose of a PET/CT examination
Introduction

ALARA principle

- As low as Reasonably Achievable (ALARA)
  - **Justification**
    - The radiation exposure must be medically indicated
      - No alternative approach without radiation exposure available
      - Check the availability of previous diagnostic CT scans
  - **Optimization**
    - The required image quality is not always the “best” image quality
      - How much CT is needed for the specific PET/CT examination
      - Take into account new developments in PET and CT instrumentation to reduce the radiation exposure
PET/CT protocols

Different strategies for CT use

- Attenuation correction (AC)
- Anatomical localization (AL)
- Diagnostic CT (D)
  - Non-enhanced
  - Contrast-enhanced
    - Single phase
    - Multiple phase

Cuocolo and Breatnach (EJ NMMI 2010)
PET/CT protocols

Is the CT contribution high?

• Radiation exposure in PET/CT arises from both internal (PET) and external (CT) sources

![Diagram showing PET/CT exposure]

Brix et al. (JNM 2005)

• As the radiation dose in PET/CT is mostly dependent on the CT protocols, a literature search on currently used CT protocols and CT dose levels in multimodality imaging was performed as part of the Peddose.net project.
Is the CT contribution high?

- Results from the literature review: data on adults

<table>
<thead>
<tr>
<th>Study</th>
<th>kVp</th>
<th>mAs</th>
<th>Compound</th>
<th>E(PET) mSv</th>
<th>E(CT) mSv</th>
<th>E(PET/CT) mSv</th>
<th>%CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huang et al. (Radiology 2009)</td>
<td>120</td>
<td>50-175</td>
<td>¹⁸F-FDG</td>
<td>6.2</td>
<td>7.2-26.0</td>
<td>13.4-34.2</td>
<td>54-76</td>
</tr>
<tr>
<td>Brix et al. (JMN 2005)</td>
<td>120-140</td>
<td>150-200</td>
<td>¹⁸F-FDG</td>
<td>5.7-7.0</td>
<td>16.7-19.4</td>
<td>22.4-26.4</td>
<td>74</td>
</tr>
<tr>
<td>Wu et al. (EJNMMI 2004)</td>
<td>140</td>
<td>64</td>
<td>¹⁸F-FDG</td>
<td>10.7</td>
<td>19.0</td>
<td>29.7</td>
<td>64</td>
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<tr>
<td>Jadvar et al. (Sem NM 2007)</td>
<td>80-140</td>
<td>130</td>
<td>¹⁸F-FDG</td>
<td>7.4</td>
<td>1.5-9.0</td>
<td>8.9-16.4</td>
<td>17-55</td>
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<tr>
<td>Gould et al. (JNM 2008)</td>
<td>120</td>
<td>50-100</td>
<td>⁸²Rb</td>
<td>4.4</td>
<td>3.0-5.4</td>
<td>7.4-9.8</td>
<td>41-55</td>
</tr>
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</table>
The review reveals a large range in CT contribution: 17-76%.
The values for low dose CT are on average below 10 mSv. This is sufficiently high compared to the radiation dose from conventional rotating rod source such as $^{68}$Ge, which is usually lower than 0.3 mSv.

The dose depends largely on the used CT protocol:
- Make sure that available CT dose reduction techniques are used:
  - Automatic Tube Current Modulation
  - Iterative Reconstruction
  - Adaptive Collimation
- The required image quality ≠ most beautiful image
PET/ CT protocols

Is the CT contribution high?

- Results from the literature review: data on children

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<tr>
<th></th>
<th>kVp</th>
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<th>Compound</th>
<th>E(PET) mSv</th>
<th>E(CT) mSv</th>
<th>E(PET/CT) mSv</th>
<th>%CT</th>
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<tr>
<td>Chawla et al.</td>
<td>110-130</td>
<td>34,4-170</td>
<td>^18^F-FDG</td>
<td>4.6</td>
<td>20.3</td>
<td>24.9</td>
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<td>(Pediatr Radiol 2010)</td>
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<td>Fahey et al.</td>
<td>120</td>
<td>100</td>
<td>^18^F-FDG</td>
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<td>9.9</td>
<td>18.3</td>
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<td>3.8-18.9</td>
<td>10.2-25.3</td>
<td>37-75</td>
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<td>(Sem NM 2007)</td>
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<td>Gelfand et al.</td>
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<td>-</td>
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<td>6.8</td>
<td>~13</td>
<td>~19.8</td>
<td>~66</td>
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<tr>
<td>Alessio et al.</td>
<td>120</td>
<td>10-40</td>
<td>^18^F-FDG</td>
<td>5.0-7.6</td>
<td>3.1-5.9</td>
<td>8.1-13.5</td>
<td>38-44</td>
</tr>
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</table>
PET/CT protocols

Is the CT contribution high?

• Concerns for the pediatric age group

  ■ This literature review revealed no significant differences in effective CT doses compared with the adult data. There is again a large range in CT contribution: 37-82%.

  ■ The axial field of view in PET/CT is much larger than that of a traditional abdominal CT and routinely extends from the base of the skull to the thigh. So the effective dose may be two or four times higher.

  ■ The use of serial PET/CT scans for follow-up in children, can contribute to a high cumulative effective dose.
PET/CT protocols

Is the CT contribution high?

- The cumulative radiation dose from serial PET/CT scans in children with malignancies: a 5-year retrospective review

Chawla et al. (Pediatr Radiol 2010)
Dedicated protocols for children

FDG Activity

- Activity calculation: e.g. EANM dosage card
- A trade-off should be made between:
  - Scan time reduction
  - Image quality improvement
  - Radiation dose reduction
Dedicated protocols for children

CT protocol

- Pediatric PET/CT acquisition protocols with CT for attenuation correction and localization with a weight-based tube current ranging from 10 to 40 mAs.
- The radiation dose corresponding to the proposed protocol is only 20-50% of the dose associated with protocols that use a fixed CT technique of 120 mAs and 120 kVp.

Alessio et al. (JNM 2007)
Summary

• CT contribution in multimodality imaging may be high
• Taken into account the higher sensitivity of pediatric patients, an adjustment of the scanning parameters to the smaller size of these patients is necessary.
• Appropriate justification and optimization is needed for setting up a CT scanning protocol for multimodality imaging, taking into account:
  ■ The age of the patient
  ■ CT dose reduction techniques
  ■ Required image quality (≠ “best” image quality)
  ■ Availability of previous diagnostic CT scans