PET/CT-MRI
First clinical experience

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PET/CT-MR Experiments and Clinical Evaluations

• Clinical workflow considerations

• Clinical Validation of PET/MR vs. PET/CT in various body regions
  => Replacement potential of PET/CT by PET/MR
    • is PET/MR superior to PET/CT?
    • for which disease is this the case?
    • for which tracers is this the case?
Overview of options (Definitions: separate vs. sequential vs. simultaneous*)

1. Separate systems
   two independent systems, patient down-/uploaded on separate system tables, connection of data through software fusion

2. Sequential systems
   systems are separate, but connected with a shuttle
   all current PET/CTs and SPECT/CTs
   - single room: Philips PET-MR
   - two room: GEHC PET/CT+MR

3. Simultaneous systems
   Siemens fully integrated PET/MR APD-based
   GE Healthcare fully integrated PET/MR, SiPM-based

Clinical workflow considerations

Protocols in simultaneous PET/MRI have to be adapted to PET-emission time. Additional dedicated ceMRI possibly afterwards.

- PET: 2'-3' data acquisition
- MR: 2'-3' to run MR seq. to obtain diagnostic MR
Clinical workflow considerations

- Whole Body (Basic MRI Protocols)
  - Basic WB - Protocol
    - Different WB-Protocols
    - Depending on the indication/disease

- Advanced Body (Advanced MRI Protocols)
  - Advanced PB - Protocols
    - Different body areas based on disease
    - Higher resolution images

Start MRI approx. 30 min after FDG-injektion
Time for MRI: ca. 30 minutes

PET/CT
Sequential PET/MRI

TOF-PET/CT
GE Disc. 690

Floor fixed shuttle

MR 3T GE 750 w
with undockable table
Sequential PET/MRI
Sequential PET/MRI
### Clinical workflow considerations

**WB Basic Protocol**

**Always:**
- WB Dixon based T1

**AND:**
- T2 (triggered) lung
- WB Cor STIR/T2

**OR:**
- WB Cor DWI

**Neck Protocol:**
- ax/sag/cor T1 / T2, DWI / Perfusion,
- post CM T1 fs (mult. planes)

**Abdomen Protocol:**
- ax/ T1 / T2, Cor FIESTA,
- triggered T2, DWI / MRCP / Perfusion,
- post CM T1 fs (mult. planes)

**Pelvic Protocol:**
- ax/cor T2 abdomen, ax T1 pelvis, triggered T2 (mult. planes)
- DWI / Perfusion,
- post CM T1 fs (mult. planes)

**Brain Protocol:**
- ax T1/T2, cor Flair, ASL /Perfusion,
- post CM T1 (mult planes)
Basic PET/MRI = PET/LavaFlex/T2 Propeller/Cor STIR
(+/- 17 minutes)
Clinical Validation of PET/MR vs. PET/CT
Whole Body Results
Clinical Validation of PET/MR vs. PET/CT
Whole Body Results

1. Comparison of PET/CT vs. PET/MRI with rapidly acquired 3.0T-MR-images using axial T1 two point dixon based GRE sequence
2. Additional trial with three sequences (T1, T2 propeller lung, cor STIR).
3. 64 patients with various oncological diseases
4. Detectability, localization, lesion size and conspicuity (qualitative score 1 (< 25% outline detectable) up to score 4 (>75% outline detectable)) were compared
5. **126 PET-positive** lesions were evaluated (abdominal, thoracic and neck lesions).
Clinical Validation of PET/MR vs. PET/CT
Whole Body Results

<table>
<thead>
<tr>
<th></th>
<th>CT score</th>
<th></th>
<th>MRI score</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percent</td>
<td>Frequency</td>
<td>Percent</td>
</tr>
<tr>
<td>1</td>
<td>17</td>
<td>13.5</td>
<td>27</td>
<td>21.4</td>
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<tr>
<td>2</td>
<td>29</td>
<td>23.0</td>
<td>23</td>
<td>18.3</td>
</tr>
<tr>
<td>3</td>
<td>26</td>
<td>20.6</td>
<td>30</td>
<td>23.8</td>
</tr>
<tr>
<td>4</td>
<td>54</td>
<td>42.9</td>
<td>46</td>
<td>36.5</td>
</tr>
<tr>
<td>Total</td>
<td>126</td>
<td>100.0</td>
<td>126</td>
<td>100.0</td>
</tr>
<tr>
<td>Mean score</td>
<td>2.93</td>
<td></td>
<td>2.75</td>
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</table>
Clinical Validation of PET/MR vs. PET/CT
Whole Body Results

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Score (mean)</th>
<th>Size mm (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axilla</td>
<td>8</td>
<td>3.88</td>
<td>9.36</td>
</tr>
<tr>
<td>Cervical</td>
<td>17</td>
<td>2.88</td>
<td>11.48</td>
</tr>
<tr>
<td>GIT + urogenital</td>
<td>10</td>
<td>2.00</td>
<td>28.22</td>
</tr>
<tr>
<td>Bladder</td>
<td>7</td>
<td>4.00</td>
<td>13.53</td>
</tr>
<tr>
<td>Breast</td>
<td>7</td>
<td>7.47</td>
<td>13.87</td>
</tr>
<tr>
<td>Medianine</td>
<td>19</td>
<td>2.68</td>
<td>20.22</td>
</tr>
<tr>
<td>Mesentery</td>
<td>8</td>
<td>2.88</td>
<td>23.24</td>
</tr>
<tr>
<td>Bone</td>
<td>19</td>
<td>2.80</td>
<td>15.17</td>
</tr>
<tr>
<td>Pleura</td>
<td>7</td>
<td>2.57</td>
<td>10.06</td>
</tr>
<tr>
<td>Lung</td>
<td>15</td>
<td>3.60</td>
<td>21.48</td>
</tr>
<tr>
<td>Retroperitoneum</td>
<td>9</td>
<td>3.67</td>
<td>27.96</td>
</tr>
</tbody>
</table>

Statistically significant superiority of CT over MRI in pulmonary lesions (p=0.016).

For all other organs/anatomical structures no significant differences between CT and MRI for lesion conspicuity and size.
# Detectability of lung lesions in MR vs low dose CT


<table>
<thead>
<tr>
<th></th>
<th>Number and Size [mm] of Nodules</th>
<th>Patient-based Detection rates (n=40)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low-dose CT</td>
<td>Water-Only MRI</td>
</tr>
<tr>
<td>All Nodules</td>
<td>n=66</td>
<td>n=56</td>
</tr>
<tr>
<td></td>
<td>19±19 (2-69)</td>
<td>18±18 (2-64)</td>
</tr>
<tr>
<td>with abnormal FDG-uptake</td>
<td>n=36</td>
<td>n=33</td>
</tr>
<tr>
<td></td>
<td>32±18 (3-69)</td>
<td>28±16 (6-64)</td>
</tr>
<tr>
<td>with background FDG-activity</td>
<td>n=30</td>
<td>n=23</td>
</tr>
<tr>
<td></td>
<td>5±5 (2-30)</td>
<td>6±10 (2-50)</td>
</tr>
</tbody>
</table>

**Note:** Detection rates of low-dose CT and MRI similar (p>0.05, each) regarding all nodules, FDG-positive, and FDG-positive nodules.

On a lesion by lesion basis, low dose CT sees more,

On a patient by patient basis, low dose CT ~ MRI
Clinical Validation of PET/MR vs. PET/CT
Abdominal PET/MRI vs. PET/CT and sequence selection

1. 43 patients (mean age 61 years, range 22 to 92 years, 23 f, 20 m)
2. T1 GRE (LAVA flex), balanced gradient echo (FIESTA), ultra fast spin echo (SSFSE)
3. Standard PET/CT with average 336 MBq 18F-FDG
4. All lesions were compared concerning detectability, anatomic allocation, size and conspicuity (score 1-4).
5. Differences were analyzed by Wilcoxon signed rank test.
<table>
<thead>
<tr>
<th>No. of lesions</th>
<th>Liver</th>
<th>Lymph nodes</th>
<th>GIT</th>
<th>Retropertioneal</th>
<th>Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26</td>
<td>20</td>
<td>7</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>CT conspicuity (1-4), mean±SD</td>
<td>1.54±0.6</td>
<td>2.85±0.6</td>
<td>1.36±0.5</td>
<td>2.13±0.9</td>
<td>3.43±1.1</td>
</tr>
<tr>
<td>LAVA conspicuity (1-4), mean±SD</td>
<td>3.81±0.6</td>
<td>3.35±0.6</td>
<td>2.82±1.0</td>
<td>3.00±1.4</td>
<td>3.71±0.4</td>
</tr>
<tr>
<td>SSFSE conspicuity (1-4), mean±SD</td>
<td>3.38±0.6</td>
<td>3.40±0.8</td>
<td>2.27±1.1</td>
<td>3.12±1.1</td>
<td>3.00±1.2</td>
</tr>
<tr>
<td>FIESTA conspicuity (1-4), mean±SD</td>
<td>3.04±0.7</td>
<td>3.45±0.6</td>
<td>2.55±1.2</td>
<td>2.57±1.2</td>
<td>2.60±1.1</td>
</tr>
</tbody>
</table>

- LAVA_conspic vs. CT_conspic
  - p** value
  - 0.000 | 0.004 | 0.006 | NS | NS |

- SSFSE_conspic vs. CT_conspic
  - p** value
  - 0.000 | 0.026 | 0.023 | NS | NS |

- FIESTA_conspic vs. CT_conspic
  - p** value
  - 0.000 | 0.005 | 0.010 | NS | NS |

- SSFSE_conspic vs. LAVA_conspic
  - p** value
  - 0.017 | NS | NS | NS | NS |

- FIESTA_conspic vs. LAVA_conspic
  - p** value
  - 0.002 | NS | NS | NS | NS |

- FIESTA_conspic vs. SSFSE_conspic
  - p** value
  - NS | NS | NS | NS | NS |

<table>
<thead>
<tr>
<th>No. of lesions</th>
<th>CT (PET/CT)</th>
<th>LAVA (PET/MRT)</th>
<th>SSFSE (PET/MRT)</th>
<th>FIESTA (PET/MRT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>74</td>
<td>74</td>
<td>74</td>
<td>71</td>
</tr>
<tr>
<td>Mean long axis diameter (range)</td>
<td>16.9 (0-79)</td>
<td>23.7 (0-88)</td>
<td>22.0 (0-85)</td>
<td>23.2 (0-70)</td>
</tr>
<tr>
<td>Mean short axis diameter (range)</td>
<td>13.8 (0-58)</td>
<td>18.9 (0-74)</td>
<td>17.6 (0-73)</td>
<td>18.9 (0-70)</td>
</tr>
<tr>
<td>Conspicuity of lesions (1-4), mean±SD</td>
<td>2.15 ± 1.0</td>
<td>3.43 ± 0.8</td>
<td>3.15 ± 0.9</td>
<td>3.00 ± 0.9</td>
</tr>
</tbody>
</table>
cePET/CT vs. non cePET/MRI: PET-MR > PET/CT
Liver/Abdominal lesions? Benefit: no contrast!
cePET/CT vs. non cePET/MRI: PET-MR > PET/CT
Liver/Abdominal lesions? Benefit: no contrast!
Liver Metastases
Ob-Gyn Cancers
GI Cancers
**GI Cancers**

**PET/MRI**
FDG-activity in a small polyp with high grade dysplasia.
Head and Neck Cancer

- A total of 150 adult patients (114 men, 36 women; mean age 64 years, range 27 – 91 years) were enrolled in this prospective study.
- All patients were referred for a clinical $^{18}$F-FDG-PET/CT exam for either staging or restaging/follow-up of various head and neck cancers.
Integrated diagnostics: PET/MR > PET/CT
Fewer artefacts
Head and Neck Cancer – Tongue
Head and Neck Cancer – Tongue
Head and Neck Cancer – mandibular invasion
Future visions – PET/CT-MRI Experimental Research
Multiparametric Imaging

PET/CT-MRI combined with DSC, ASL, Diffusion...

...combined with PET-perfusion

...combined with CT-perfusion

...combined with IVIM
Selection of current clinical research trials

- Work-Flow Evaluation
- Body Coil Evaluation
- „Low-Dose“ WB-PET/MRI
- Lymphoma trial
- Head and Neck Cancer
- Abdominal PET/MRI vs. PET/CT and sequence selection
- cePET/CT vs. non cePET/MRI
- OB-Gyn trial
- PET/CT vs. PET/MRI in lung lesions
- MR-AC development, metal artifact correction in PET/CT-MRI
- Cardiac PET-MRI
- Prostate PET/MRI
- Perfusion trial series
- ...
Conclusions – Clinical

1. Clinically, PET-MR does measure up to PET/CT

2. „High quality“ anatomic referencing in the entire body incl. chest!

3. Possible advantages:
   - Head and Neck cancer, RT-planning, abdominal/pelvic tumors (poss. no contrast needed), prostate cancer, lymphoma, patient comfort.

4. PET/CT-MRI or PET/MRI can be used as „one-stop-shop“ imaging in cases where CT cannot provide adequate T-stage
Conclusions – Clinical

5. Sequences still need to be adapted and need to be faster for whole-body overview in acceptable time.

6. Lung imaging: techniques are on the way – but the way is still very long

Tri-modality PET/CT+MR is able to deal with all these issues and generate the comparative data of PET/CT and PET/MRI.
Thank you very much for your attention.