Use of molecular and functional imaging for treatment planning
The Good, The Bad and The Ugly

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Molecular and functional imaging

- **Molecular Imaging:** “Visualization, characterization and measurement of biological processes at the molecular and cellular levels in humans and other living systems”
  - It can probe molecular abnormalities that are the basis of disease rather than image the end effects

- **Functional Imaging:** “Visualization, characterization and measurement of organ function in humans and other living systems”
  - It can probe functional status of an organ, which is direct consequence of disease or treatment

See *in vivo* what we can see *in vitro*

Paradigm shift in imaging

- From **QUALITATIVE** DIAGNOSTIC IMAGING (Diagnosis and Staging)…

- …To **QUANTITATIVE** THERAPEUTIC IMAGING (Target definition, Treatment assessment)

- **Limited experience** with imaging in treatment context, compared to diagnostic (except CT)!

- **Dangerous** to use diagnostic quality imaging in a therapeutic context (*Qualitative ≠ Quantitative*)
PET imaging uncertainties

- Technical factors
  - Relative calibration between PET scanner and dose calibrator (10%)
  - Residual activity in syringe (5%)
  - Incorrect synchronization of clocks (10%)
  - Injection vs calibration time (10%)
  - Quality of administration (50%)

- Physical factors
  - Scan acquisition parameters (15%)
  - Image reconstruction parameters (30%)
  - Use of contrast agents (15%)

- Analytical factors
  - Region of interest (ROI) definition (50%)
  - Image processing (25%)

- Biological factors
  - Patient positioning (15%)
  - Patient breathing (30%)
  - Uptake period (15%)
  - Blood glucose levels (15%)

Jeraj 2010
Current state of affairs...

What is the real tumor extent?

Different modalities – different answer

<table>
<thead>
<tr>
<th>Pair</th>
<th>Misaligned Volume (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT to MR imaging</td>
<td>26 (6.2/23.8)</td>
</tr>
<tr>
<td>CT to FDG PET</td>
<td>48 (7.6/16.3)</td>
</tr>
<tr>
<td>MR imaging to CT</td>
<td>81 (6.9/73.2)</td>
</tr>
<tr>
<td>CT to FDG PET</td>
<td>45 (9.3/20.8)</td>
</tr>
<tr>
<td>MR imaging to CT</td>
<td>67 (11.0/52.3)</td>
</tr>
<tr>
<td>FDG PET to CT</td>
<td>107 (14.3/41.7)</td>
</tr>
<tr>
<td>FDG PET to MR imaging</td>
<td>17 (3.5/20.8)</td>
</tr>
<tr>
<td>FDG PET to CT</td>
<td>15 (3.6/21.8)</td>
</tr>
<tr>
<td>CT to specimen</td>
<td>86 (6.8/72.4)</td>
</tr>
<tr>
<td>MR imaging to CT</td>
<td>10 (2.0/20.8)</td>
</tr>
<tr>
<td>MR imaging to FDG PET</td>
<td>9 (2.2/21.8)</td>
</tr>
<tr>
<td>CT to FDG PET</td>
<td>15 (2.1/16.5)</td>
</tr>
</tbody>
</table>

Note: Data in parentheses are the average misaligned volumes in cubic centimeters.

Same modality – different answers

FDG PET/CT
Imaging uncertainties – extra margins

<table>
<thead>
<tr>
<th>Margin Plane</th>
<th>Mean ± SD (mm)</th>
<th>Maximum (mm)</th>
<th>Avg. Max ± SD (mm)</th>
<th>Maximum (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial</td>
<td>1.0 ± 0.4</td>
<td>1.8</td>
<td>8.4 ± 6.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Coronal</td>
<td>0.5 ± 0.3</td>
<td>1.2</td>
<td>10.6 ± 6.1</td>
<td>26.7</td>
</tr>
<tr>
<td>Sagittal</td>
<td>0.5 ± 0.3</td>
<td>1.2</td>
<td>10.2 ± 5.3</td>
<td>22.1</td>
</tr>
</tbody>
</table>

And here comes DOSE PAINTING...


Spatial distribution of tumor phenotypes

FDG PET/CT (metabolism)  FLT PET/CT (proliferation)  Cu-ATSM PET/CT (hypoxia)

Spatial distribution of tumor phenotypes

FDG PET/CT (metabolism)  FLT PET/CT (proliferation)  Cu-ATSM PET/CT (hypoxia)
How to combine this information?

Uniform dose → Non-uniform dose

Symposium

- **Yue Cao**: MRI for Radiation Treatment Planning
- **Dimitris Visvikis**: The Good, the Bad and the Ugly About Using PET for Treatment Planning
- **Vincent Gregoire**: This House Believes That the Use of Functional Imaging for Treatment Planning of Head and Neck Tumors Need to be Carefully Considered