Analysis of differences between $^{99m}$Tc-MAA-SPECT and $^{90}$Y-Microsphere-PET dosimetry

Marilyne Kafrouni, Marjolaine Fourcade, Sébastien Vauclin, Alina-Diana Ilonca, Denis Mariano-Goulart, Fayçal Ben Bouallège

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PhD in collaboration between:

DOSIsoft & CHU
Introduction
Analysis of differences between $^{99m}$Tc-MAA-SPECT and $^{90}$Y-Microsphere-PET dosimetry

**Introduction**

1. Simulation

- Procedure implies:
  - Reproducibility
  - Vascularization

2. Treatment

- Different particles:
  - Size
  - Density
  - Number of particles

- Different imaging modality:
  - Isotope
  - S/B Ratio

Predictive Dosimetry

Post-treatment Dosimetry
Materials & Methods
Population

- 20 patients
- 21 treatments
- Between 2015 and 2018
- HCC (intermediate or advanced)
- Glass microspheres (TheraSphere®, BTG)
- Time between MAA and microsphere injection: 18 ± 7 days
- Administered activity: 3.7 ± 1.2 GBq
- Lung shunt: 2.4 ± 4.3 %
- Tumor volume: 514 ± 407 mL
1. Segmentation

- Radiology team
- Total liver + Lesion(s) > 2cm
- AW Workstation (GE Healthcare, Waukesha, WI, USA)

2. Predictive Dosimetry

- Multi-modal registration
- $^{99m}$Tc-MAA SPECT based dosimetry
- PLANET® Dose (DOSIsoft, Cachan, France)

3. Post-treatment Dosimetry

- Multi-modal registration
- $^{90}$Y-Microsphere PET based dosimetry
- PLANET® Dose (DOSIsoft, Cachan, France)
Abdo-Man: a 3D-printed anthropomorphic phantom for validating quantitative SIRT

Jonathan I. Gear¹, Craig Cummings², Allison J. Craig¹, Antigoni Divoli¹, Clive D. C. Long¹, Michael Tapner² and Glenn D. Flux¹

- $^{99m}$Tc Activity: 315 MBq
- $^{90}$Y Activity: 2.6 GBq
- Tumor/Normal Liver 5:1
Analysis of Differences

Predictive vs. Post-treatment Dosimetry

→ Planned vs. delivered activity
→ Interventional Radiology
→ Phantom
→ Imaging
Results
### Dose Results

#### Mean, SD, Range

<table>
<thead>
<tr>
<th></th>
<th>$^{99m}$Tc-MAA</th>
<th>$^{90}$Y-Microsphere</th>
<th>Student’s Test (p)</th>
<th>Pearson’s Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{avg}$ Tumor (Gy)</td>
<td>Mean</td>
<td>SD</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>209</td>
<td>56</td>
<td>141-373</td>
<td>161</td>
</tr>
<tr>
<td>$D_{avg}$ Normal Liver (Gy)</td>
<td>Mean</td>
<td>SD</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>16</td>
<td>11-75</td>
<td>35</td>
</tr>
</tbody>
</table>

#### MAA vs. $^{90}$Y Mean Deviation

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>$D_{avg}$ Tumor</td>
<td>25 ± 12 %</td>
</tr>
<tr>
<td>$D_{avg}$ Normal Liver</td>
<td>27 ± 12 %</td>
</tr>
</tbody>
</table>
Analysis of differences between $^{99m}$Tc-MAA-SPECT and $^{90}$Y-Microsphere-PET dosimetry

**Correlation**

**Planned vs. Delivered Average Dose**

- **Tumor**
  - $\rho = 0.81$
  - $p = 1.10^{-5}$

- **Normal Liver**
  - $\rho = 0.88$
  - $p = 1.10^{-7}$

**Bland-Altman Plot**

- **Tumor**
  - $\rho = -0.21$
  - $p = NS$

- **Normal Liver**
  - $\rho = -0.25$
  - $p = NS$
Clinical differences

Wished vs. Delivered Activity: 7 ± 8 %

- Vial Selection
- Vial Calibration
- Injection Time
- Residual Activity

Radiological Gesture:

- Same Operator: 9/21
- Same Material used: 14/20 (1 NA)
- Same Position: 16/20 (1 NA), 4 slightly different positions
- Volume of Injection: 5 mL of MAA vs. 60 mL of microspheres (including rinsing)
### Analysis of differences between $^{99m}$Tc-MAA-SPECT and $^{90}$Y-Microsphere-PET dosimetry

<table>
<thead>
<tr>
<th></th>
<th>$D_{avg}^{99mTc}$</th>
<th>$D_{avg}^{90Y}$</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogeneous Sphere</td>
<td>236 Gy</td>
<td>225 Gy</td>
<td>-5%</td>
</tr>
<tr>
<td>Necrotic Sphere</td>
<td>178 Gy</td>
<td>211 Gy</td>
<td>19%</td>
</tr>
<tr>
<td>Normal Liver</td>
<td>60 Gy</td>
<td>59 Gy</td>
<td>-2%</td>
</tr>
</tbody>
</table>
- Low branching ratio ($31.86 \times 10^{-6}$)
- Large random fraction (Bremsstrahlung + $^{176}$Lu)
- Scatter correction
- Misplaced counts (Willowson et al.)
- Large spheres, recovery of 80% (Carlier et al.)

90Y-PET Imaging: Exploring limitations and accuracy under conditions of low counts and high random fraction

Thomas Carlier, Kathy P. Willowson, Eugene Fourkal, Dale L. Bailey, Mohan Doss, and Maurizio Conti

Citation: Medical Physics 42, 4295 (2015); doi: 10.1118/1.4922685

Quantitative 90Y image reconstruction in PET

Kathy Willowson, Nicholas Forwood, Bjoern W. Jakoby, Anne M. Smith, and Dale L. Bailey

Citation: Medical Physics 39, 7153 (2012); doi: 10.1118/1.4762403

NEMA/IEC 2001 $^{90}$Y solution

\[
\frac{\text{Injected Activity}}{\text{Activity in the Field of View}} = 1.03
\]
Planned MAA-based dosimetry vs. $^{90}$Y post-treatment dosimetry:

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<th>$^{90}$Y-Microsphere</th>
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<td>16</td>
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Renormalized MAA-based dosimetry vs. $^{90}$Y post-treatment dosimetry:

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<th>$^{99m}$Tc-MAA</th>
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<th>Student’s Test (p)</th>
<th>Pearson’s Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>$D_{avg}$ Tumor</td>
<td>164</td>
<td>40</td>
<td>115-281</td>
<td>161</td>
</tr>
<tr>
<td>$D_{avg}$ Normal Liver</td>
<td>36</td>
<td>15</td>
<td>8-69</td>
<td>35</td>
</tr>
</tbody>
</table>

→ Dose deviations mainly related to imaging modality differences
Discussion/Conclusion
Discussion/Conclusion

Better tumor targeting during treatment

Although planned vs. delivered dosimetry are significantly different, they are correlated → $^{99m}$Tc-MAA-based dosimetry is today the best option for dosimetry planning.

- Residual Activity
- Injection Time
- $^{90}$Y-PET Quantification
Analysis of differences between $^{99m}$Tc-MAA-SPECT and $^{90}$Y-Microsphere-PET dosimetry.
Analysis of differences between $^{99m}$Tc-MAA-SPECT and $^{90}$Y-Microsphere-PET dosimetry

### Clinical Case

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<tr>
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<th>$^{90}$Y-Microspheres</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{\text{avg}}$</td>
<td>128 Gy</td>
<td>99 Gy</td>
</tr>
<tr>
<td>$D_{70}$</td>
<td>83 Gy</td>
<td>31 Gy</td>
</tr>
<tr>
<td>$D_{50}$</td>
<td>127 Gy</td>
<td>59 Gy</td>
</tr>
<tr>
<td>$D_{\text{avg-NL}}$</td>
<td>31 Gy</td>
<td>32 Gy</td>
</tr>
</tbody>
</table>

$V_{\text{Tumor}} = 119 \text{ mL}$

Different Operator and Catheter

$\rightarrow$ Different MAA and microsphere distributions
SPECT

Symbia Intevo (Siemens)
Window: 140 keV ± 7.5%
32 projections
25s/projection
Matrix: 128 x 128
Voxel size: 4.79 x 4.79 x 4.79 mm³
Low Energy Collimator
Flash 3D Iterative Reconstruction
5 iterations/8 subsets
Attenuation and Scatter corrections
Acquisition Time: 16 min

PET

Biograph mCT (Siemens)
1 bed (20 min)
Matrix: 200 x 200
Voxel size: 2.04 x 2.04 x 2.04 mm³
PSF (TrueX) + TOF
2 iterations/21 subsets
All-Pass Filter
Attenuation and Scatter corrections
Acquisition Time: 20 min