PERSONALIZED DOSIMETRY IN $^{90}$Y-MICROSPHERES THERAPY OF LIVER CANCER USING THE OÉDIPE SOFTWARE AND SPECT-CT IMAGES

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The Selective Internal Radiation Therapy (SIRT)

- **General principle**

  - **Alternative therapy for the treatment of unresectable liver cancers**
    - Transfemoral catheterization under fluoroscopic guidance
    - Injection of $^{90}$Y-microspheres in the hepatic artery

  - **Selective irradiation of tumoral tissue**
    - Resulting from differences in the blood supplies of tumoral tissue and healthy liver
    - Depending on the type of disease (hepatocellular carcinoma or hepatic metastases)

- A radiopharmaceutical being injected, the optimization principle must be respected to ensure the patient’s radiation protection and the efficiency of the treatment.
The Selective Internal Radiation Therapy (SIRT)

**Treatment steps**

- **Patient eligible for SIRT**

  ![Image](589x9 to 651x28)

  ![Image](34x362 to 205x411)

  ![Image](1x30 to 709x361)

- **Evaluation**
  - **Tumor cartography**:
    - High resolution CT scan
    - $^{18}$F-FDG PET/CT scan
  - **Vascular cartography**:
    - Hepatic angiography with prophylactic embolization
    - **Sphere 1** = $^{99m}$Tc-MAA injection followed by a SPECT/CT scan and a whole body scintigraphy

- **Treatment**
  - **Sphere 2**
    - $^{90}$Y-microspheres injection followed by a SPECT/CT scan and a whole body scintigraphy

The Selective Internal Radiation Therapy (SIRT)

**Pre-dosimetry - Clinical practice**

**BSA method (Body Surface Area)**

The activity to inject depends on:
- Tumor burden (%)
- Patient’s height and weight
- Pulmonary fixation

\[ A_{\text{injected}} (GBq) = (\text{BSA} - 0.2) + \frac{V_{\text{tumor}}}{V_{\text{whole liver}}} \]

**HYPOTHESIS: PERFECT SELECTIVITY OF THE THERAPY**

⇒ Overestimation of the tumor absorbed dose and underestimation of the healthy liver absorbed dose
⇒ Optimization principle non respected

**Partition model**

The activity to inject depends on:
- Pulmonary fixation
- Healthy liver fixation
- Tumor fixation

**3 compartments:**
- Lungs
- Healthy liver
- Tumor

**2 limiting criteria:**
- \( D_{\text{lungs}} < 15 \text{ Gy} \)
- \( D_{\text{healthy liver}} < 30 \text{ Gy} \)

⇒ More realistic consideration of the therapy selectivity
⇒ **LIMITATION:** Absorbed doses calculated considering a uniform activity distribution within the compartments

**NEED FOR A PRECISE AND REALISTIC DOSIMETRY**
The personalized 3D dosimetry

**General principle**

A method which combines:

- The patient-specific geometry
- The patient-specific biodistribution of the radiopharmaceutical
- Monte Carlo calculations

**General principle**

- **Geometry** (Patient’s anatomy)
- **Activity at the voxel scale** (Patient’s biodistribution)
- **Physical characteristics** - radionuclide - tissues

**MCNPX**

- **Input file**
- **Output file**

**RESULTS DISPLAY**

- Absorbed doses in each Region Of Interest
- Isodose curves superimposed on anatomical images
- Dose Volume Histograms (DVHs)
The personalized 3D dosimetry

**MCNPX input file generation**

1. **Organs Contouring**
   - IsoGray - Dosisoft (France)

2. **Image Registration**
   - SPECT/VOXEL PHANTOM

3. **Selection of the abdominal region**
   - Redimensionnement
   - Uniformisation

4. **OEDIPE**
   - 128x128x128          128x128x95
   - 4,088x4,088x3,27 mm³
   - 4,41806x4,41806x4,41806 mm³

5. **Source Definition at the voxel scale**

6. **Physical characteristics of 90Y and tissues**

7. **MCNPX Input File**
   - Tally F6 (Quantity of energy delivered per unit mass in a cell)
   - 100 millions of particles
The personalized 3D dosimetry

Results - Application to a patient study

TREATMENT: Woman - 70 yo - 1.61m - 55 kg - Whole liver treatment
APPLICATION: Biodistribution SPHERE 1 - $^{90}$Y injected activity: 0.74 GBq

Mean absorbed doses to ROIs
Isodoses curves superimposed to the voxel phantom
Dose Volume Histograms (DVHs)

<table>
<thead>
<tr>
<th>Tissue Type</th>
<th>BSA method</th>
<th>Partition model</th>
<th>Personalized 3D dosimetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remaining tissue</td>
<td>-</td>
<td>-</td>
<td>0.52</td>
</tr>
<tr>
<td>Left lung</td>
<td>-</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Right lung</td>
<td>-</td>
<td>-</td>
<td>0.59</td>
</tr>
<tr>
<td>Healthy liver</td>
<td>0.00</td>
<td>30.01</td>
<td>20.69</td>
</tr>
<tr>
<td>Tumor</td>
<td>644.62</td>
<td>60.42</td>
<td>44.23</td>
</tr>
</tbody>
</table>
The personalized 3D dosimetry

**Results - Application to a patient study**

**TREATMENT:** Woman - 70 yo - 1.61m - 55 kg - Whole liver treatment

**APPLICATION:** Biodistribution SPHERE 1 - $^{90}$Y injected activity : 0.74 GBq

[Graph showing Dose-Volume Histogram for SPHERE 1]

Mean absorbed doses to ROIs

Isodoses curves superimposed to the voxel phantom

Dose Volume Histograms (DVHs)

Healthy liver tolerance criterion : $V_{30Gy} < 50\%$

Optimal activity : $A_{injected} = 1.33$ GBq

MCNPX output file
Conclusions

- **Feasibility of a personalized 3D dosimetry using:**
  - Patient’s anatomy
  - SPECT/CT images
  - Monte-Carlo calculations

- **Different types of results:**
  - Calculations of mean absorbed doses
  - Display of isodoses curves superimposed to the geometry
  - Generation of DVHs

- **Optimization of the treatment maximizing treatment efficiency while ensuring patient’s radiation protection**
THANK YOU