90Y-Microsphere Therapy: Emerging Trends and Future Directions

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Manufacturer’s Instructions

<table>
<thead>
<tr>
<th>Theramine®</th>
<th>SIR-Spheres®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics</td>
<td>-25 μm glass, -2500 Bq/sphere</td>
</tr>
<tr>
<td>Indication for use</td>
<td>Hepatocellular carcinoma, Liver metastases from primary colorectal cancer</td>
</tr>
<tr>
<td>Contraindications</td>
<td>Severe liver dysfunction, extrahepatic deposition, high bilirubin, low albumin, portal vein occlusion, Clinical liver failure, extrahepatic deposition, high bilirubin, low albumin, portal vein thrombosis</td>
</tr>
<tr>
<td>Lung limits</td>
<td>30 Gy</td>
</tr>
<tr>
<td>Dose range</td>
<td>80 – 150 Gy</td>
</tr>
<tr>
<td>Activity (GBq) to treat liver lobe</td>
<td>Typically less than 80 Gy</td>
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</table>

Pre-treatment Measurements

SIR-Spheres®  TheraSphere®  Dose Calibrator
Treatment Setup and Delivery

**Treatment Cart**
- Delivery device
- Waste container
- Tube fill in lead pot

**Treatment Delivery**
- Delivery device
- Hub
- Outlet tubing
- Absorbent sheet
- Dose vial in lead pot

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Post-administration

- Dose-vial, tubing, drapes are transferred to waste container
- Survey staff, cart, and procedure room for contamination
- SIR-Spheres® – assay vial in dose calibrator
- TheraSphere® – exposure rate of residual in waste container

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TheraSphere® – Dose Delivery Efficiency

- **Pre-treatment**
- **Post-treatment**

Delivery Efficiency = (1 – Post/Pre) * 100%
Decay in storage

- 1 month - ten $^{90}$Y half-lives
- TheraSphere® – small amounts of long-lived radioactive by-products ($^{90}$Y)

Radiation Safety

- $^{90}$Y is $\beta^-$ emitter
  - Half-life: 2.7 days
  - $E_{\beta^-} = 0.93$ MeV, $E_{\beta^-}^{\max} = 2.3$ MeV
  - Range in water: 2.5 mm (mean), 11 mm (max)
  - Bremsstrahlung
- Typical patient exposure rates
  - Max surface: 5 – 25 mR/h
  - 1 meter: 0.1 – 0.3 mR/h
- NRC – no release criteria or restrictions

Pre-treatment angiography
Pre-treatment $^{99m}$Tc-MAA Scan

Planar Image

SPECT/CT

Standard Model

\[ A_{\text{Total}} = A_{\text{Liver}} + A_{\text{Lung}} \]

\[ LSF = \frac{\text{Lung counts}}{\text{Lung counts} + \text{Liver counts}} \]

\[ D_{\text{Lung}} = \left( \frac{50}{M_{\text{Lung}}} \right) \frac{A_{\text{Lung}}}{A_{\text{Total}} \times (1 - LSF)} \]

\[ D_{\text{Liver}} = \left( \frac{50}{M_{\text{Liver}}} \right) \frac{A_{\text{Liver}}}{A_{\text{Total}} \times (1 - LSF)} \]

Standard Model

- Average liver dose
- Within recommended dose range
- What about….?
  - Heterogeneous uptake distribution?
  - Tumor dose?
  - Normal tissue dose?

\[ D_{\text{Lobe}} = 120 \text{ Gy} \]
**Partition Model**

\[ D_{\text{Liver}} M_{\text{Liver}} = D_{\text{Tumor}} M_{\text{Tumor}} + D_{\text{Normal}} M_{\text{Normal}} \]

\[ D_{\text{Tumor}} = \left( \frac{T}{N} \right) D_{\text{Normal}} \]

\[ \left( \frac{T}{N} \right) = \frac{\text{Tumor activity conc}}{\text{Normal tissue activity conc.}} \]

\[ D_{\text{Tumor}} = \left( \frac{T}{N} - 1 \right) \frac{D_{\text{Liver}} M_{\text{Liver}}}{M_{\text{Tumor}} M_{\text{Liver}}} + 1 \]

\[ T = \text{Tumor activity conc.} \]

\[ N = \text{Normal tissue activity conc.} \]

**Tumor Delineation**

CT

MR

C-arm CBCT

99mTc-MAA SPECT/CT
IR/NM Collaboration

IR Physician

NM Physician

T/N Uptake Ratio (Vascularity Ratio)

- Obtain via threshold of MAA SPECT data
- Determine tumor and normal tissue uptake conc.
- T/N = 5

99mTc-MAA SPECT/CT

Dosimetry depends on model

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<th>Normal Tissue</th>
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<tr>
<td>Partition</td>
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<td>63 Gy</td>
<td>205 Gy</td>
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\[ D_{\text{Tumor}} = T \cdot N \cdot D_{\text{Liver Lobe}} - T \cdot N - 1 \cdot M_{\text{Tumor}} + 1 \]

\[ D_{\text{Liver Lobe}} = 50 \text{ GBq} \times A_{\text{Total}} \times (1 - LSF) \]

Dosimetry depends on model

*Assume T/N = 3

99mTc-MAA SPECT/CT

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99mTc-MAA SPECT/CT
Radiation Segmentectomy

- Very high dose to isolated segment(s)
- Ablation
- 360 Gy to segments 5 & 8
- Small volume
  - Relatively low $A_{\text{Total}}$
  - Limited lung dose – 8 Gy

Conclusion

Thank you
Example

- Volumes: A/B = 2
- Lung Shunt Fraction
  - Measured: 20%
  - Assume:
    - LSF_A = 20%
    - LSF_B = 20%
  - What if:
    - LSF_A = 40%
    - LSF_B = 0%

Dosimetry – Partition Model

\[ A_{Total} = A_{Lobe} + A_{Lung} \]
\[ D_{Lung} = \frac{(50 \text{ J/GBq}) \times A_{Total} \times (LSF)}{M_{Lung}} \]
\[ D_{Lobe} = \frac{(50 \text{ J/GBq}) \times A_{Total} \times (1-LSF)}{M_{Lobe}} \]
\[ D_{Tumor} = \frac{1}{\alpha} \times D_{Normal} \]
\[ D_{Lobe}M_{Lobe} = D_{Tumor}M_{Tumor} + D_{Normal}M_{Normal} \]
Dosimetry: Tumor and Normal Tissue

- SIR Spheres therapy doses are based on activity (not target radiation dose) – maximum activity of 81 mcC
- Empirical dosimetry models
  - Brain: Activity based on maximal activity & tumor fraction
  - SMA: Activity based on IDA & tumor fraction in 24h
  - Lung Stent modification: Recurrence for L > 20%
- Average liver dose < 80 Gy and lung dose < 25 Gy