A practical measure in personnel dose reduction for $^{90}\text{Y}$-micropsheres liver-directed radioembolization: from radiology department to patient ward

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Physicistic Radiology/QMH
What is Radioembolization?

• Radiation therapy and embolization to treat cancer of the liver, also known as Selective Internal Radiation Therapy (SIRT)

• Embolization is used to occlude blood flow.

• Radiation therapy uses ionizing radiation to kill cancer cells and shrink tumors.

• Radioembolization involves placing a radioactive material, tiny glass or resin beads called microspheres directly at the tumor site.

• Multidisciplinary nature involving oncologist, nuclear medicine physician, interventional radiologist & medical physicist
Flow chart to begin with

Patient selection and informed consent

$^{99m}$Tc-MAA nuclear medicine scan

Lung shunting & TN ratio calculation

Dosimetry: dose to liver, tumor, lung. Ordering

Isotope receipt & QA, then dispense

Treatment session & associated radiation protection during and after treatment

Patient observation after treatment for overnight

Nuclear medicine imaging for documentation, within a week after the treatment

Patient release & radiation protection advice

Surgeons/Radiation Oncologists/Interventional Radiologists

NM physicians/physicist

Medical Physicists

Medical Physicists

Medical Physicist

Interventional Radiologists/Radiation Oncologists/Physicist

Radiation Oncologists/Physicist

Nuclear Medicine physicians/Physicist

Radiation Oncologists/Physicists
Some basics of 90Y & μ-spheres

- Yttrium-90 is a high energy ‘pure’ beta emitting isotope: good for therapy; no good for imaging
- Mean energy: 0.93 MeV (2.27 MeV maximum)
- Half-life time: 64.1 hours
- Range max: 11 mm in tissue
- pair production abundance of $^{90}$Y ($32 \times 10^{-6}$)
Y-90 agents currently available: TheraSphere (glass) & SIR-Sphere (resin)

<table>
<thead>
<tr>
<th></th>
<th>TheraSphere</th>
<th>SIR-Sphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery agent</td>
<td>Glass beads</td>
<td>Resin beads</td>
</tr>
<tr>
<td>Particle size</td>
<td>20-30 µm</td>
<td>20-60 µm</td>
</tr>
<tr>
<td>Energy per particle</td>
<td>2500 Bq</td>
<td>50 Bq</td>
</tr>
<tr>
<td>Typical dose</td>
<td>1-4 GBq (120 Gy)</td>
<td>1-2 GBq (30-50 Gy)</td>
</tr>
<tr>
<td>Particles per dose</td>
<td>0.4-0.8 million</td>
<td>20-40 million</td>
</tr>
<tr>
<td>Embolic effect</td>
<td>Minimal</td>
<td>Variable</td>
</tr>
<tr>
<td>FDA approval</td>
<td>HCC¹</td>
<td>Colorectal metastases</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Nordion (Canada)</td>
<td>Sirtex Medical (Australia)</td>
</tr>
</tbody>
</table>

Experience in QMH: max activity SIR-Sphere = 2.5 GBq; max activity of TheraSphere = 4.5 GBq
How it works?

- Local delivery of the MAA (diagnostic) or μ-particles (therapy) into the tumor bed via hepatic artery
- For $^{99m}$Tc-MAA, mean particle size 50 μm, for $^{90}$Y-sphere 30 μm, so they are comparable in size
- These particles are small enough to reach the capillary bed, but large enough to be trapped there.
- The same procedure is repeated for $^{99m}$Tc-MAA and $^{90}$Y-sphere
Use of 4 mCi $^{99m}$Tc-MAA diagnostic NM scan

Suggest to NM image right after the Tc99m-MAA infusion.

- Geometric mean
- Lung shunting = $\frac{\text{Lungs}}{(\text{Lungs} + \text{Liver})} \times 100\%$
- TN ratio = $\frac{\text{Tumor}}{(\text{normal liver})}$
- For a suitable patient candidate: low lung shunting and high TN ratio
Example of lung shunting & TN ratio calculation

ANT CH

Lung

POST CH

ANT ABD

POST ABD

Ant Lung Counts: 18658
Post Lung Counts: 18766
Geometric Lung Counts: 18711

Ant Liver Counts: 1253663
Post Liver Counts: 556942
Geometric Liver Counts: 835594
Liver Area: 10500

Ant Tumour Counts: 961418
Post Tumour Counts: 357027
Geometric Tumour Counts: 585877
Tumour Area: 1916

Normal Liver Counts: 249717
Normal Liver Area: 8684

Tumour Count Density: 305.78
Liver Count Density: 26.75
(Exclude Tumour)

Lung Shunting: 2.19%
Tumour-to-Liver Ratio: 10.63
SPECT/CT is used nowadays:
SIRT dose calculation (BSA method)

Radioactivity (GBq) = (BSA - 0.2) + \frac{\text{tumor volume}}{\text{tumor volume} + \text{normal liver volume}}

BSA(m^2) = 0.20247 \times \text{Height (m)}^{0.725} \times \text{Weight (kg)}^{0.425}
Dose Calculations for SIR-Sphere Microspheres Implant Procedure

Please do not in anything in the column

1. Body Surface Area (BSA) Method

Height = 1.71 m
Weight = 78.2 kg

Volume of tumour (cc) = 158.47
Volume of normal liver (cc) = 1275.45

\[ BSA = \frac{\text{Height} \times \text{Weight}}{\sqrt{\text{Height} + \text{Weight}}} \]
\[ BSA = \frac{1.71 \times 78.2}{\sqrt{1.71 + 78.2}} \]
\[ BSA = 1.9050 \text{ m}^2 \]

Activity = 1.8155 GBq

2. Partition Model for Calculation of Dose/Activity of SIR-Spheres Microspheres

2.1 Breakthrough Scans

\[ A'_{\text{lung}} = \text{kBq} \]
\[ A'_{\text{tumor}} = \text{kBq} \]
\[ A'_{\text{liver}} = \text{kBq} \]

\[ m_{\text{lung}} = \text{g} \]
\[ m_{\text{tumor}} = \text{g} \]
\[ m_{\text{liver}} = \text{g} \]

\[ L = \text{g} \]
\[ T/N = \text{g} \]

2.2 Lung

\[ D_{\text{lung}} = \text{Gy} \]

Activity = GBq

2.3 Liver

\[ D_{\text{liver}} = \text{Gy (cirrhosis)} \]
\[ D_{\text{liver}} = \text{Gy (normal liver parenchyma)} \]

Activity = GBq
Patient radioactivity calculation for TheraSphere

<table>
<thead>
<tr>
<th>Patient Name:</th>
<th>Patient ID:</th>
<th>Target Tissue: whole liver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Volume (cc):</td>
<td>953.4</td>
<td></td>
</tr>
<tr>
<td>Desired Dose (Gy):</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>Time Zone Variance (h):</td>
<td>-12</td>
<td>(see Time Zones tab for details)</td>
</tr>
<tr>
<td>Lung Shunt Fraction (% LSF):</td>
<td>10.45%</td>
<td>Places in this Time Zone: Indonesia Thailand</td>
</tr>
<tr>
<td>Anticipated Residual Waste (%):</td>
<td>1.00%</td>
<td>Optional estimated value</td>
</tr>
<tr>
<td>Previous Dose to the Lungs (Gy):</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Required Activity at Administration (GBq):</td>
<td>2.19</td>
<td>This value is corrected for LSF and Residual Waste if values are entered above.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculated Dose to Lungs (Gy): 11.35</th>
<th>Dose Limit to the Lungs per treatment (Gy): 30</th>
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</thead>
<tbody>
<tr>
<td>Lung Dose within recommended limit for treatment</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Cumulative Dose to Lungs (Gy): 11.35</th>
<th>Cumulative Dose Limit to the Lungs (Gy): 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung Dose within recommended cumulative limit for treatment</td>
<td></td>
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To prepare the Tx session

Dose package & dispense

Items needed for SIRT Tx session
Steps to dispense the μ-spheres patient dose in lab

Assume 3 GBq in 5 ml on Tx day.
Patient prescription = 2 GBq
I need to draw \((5\times2/3\text{ ml}) = 3.33\text{ ml}\)
Then I draw just a bit more than 3.33 ml.
Slowly infuse into the v-vial

Actual radioactivity in v-vial = (initial act of glass vial - remaining act of glass vial - act of the syringe)
IR room radiation protection: before the SIRT session

- Protective wrap around the x-ray head & detector
- Place an absorbent paper where the injection trolley is located to localize any possible radiation spillage
Delivery technique about the same for the two types of spheres

SIR-Sphere delivery box

TheraSphere delivery box
Personnel radiation protection in IR room: immediately after SIRT infusion: use of lead lined blanket
Dose measurement for radiologist with and without using the blanket

<table>
<thead>
<tr>
<th>Use of lead lined blanket</th>
<th>Normalized average dose rate [μSv/(hr•GBq)]</th>
<th>Radiologist position</th>
<th>At 10 cm above patient abdomen</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>2.91</td>
<td>8.41</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.32</td>
<td>3.10</td>
<td></td>
</tr>
</tbody>
</table>

p-value: < 0.01 < 0.01
Occupation dose for different hospital personnel handling the Y90 patient

<table>
<thead>
<tr>
<th>Staff</th>
<th>Procedure</th>
<th>Estimated time spent (min)</th>
<th>Occupational dose (µSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiologist</td>
<td>Puncture site pressing</td>
<td>20</td>
<td>0.92 on hand 0.4 under apron</td>
</tr>
<tr>
<td>Nurse</td>
<td>Patient transfer</td>
<td>5</td>
<td>0.52</td>
</tr>
<tr>
<td>Porter</td>
<td>Patient transport</td>
<td>5</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Background about 6 µSv in QMH area
Personnel radiation survey after treatment: any contaminated items are collected for ‘store & decay’
Radiation survey the IR room after treatment

absorbent placed before SIRT
What radiation protection to patients after SIRT?

- Patients will be under clinical observation after SIRT
- If infused Y$_{90} \geq 1.5$ GBq, patient has to stay in isolation ward with private toilet facility according to HA Code of Practice on radiation safety 2011.
- Patient will stay in isolation ward until his/her remaining Y$_{90} < 1.5$ GBq

An example: patient given 4.75 GBq on 5/May/15 noon (Tue)
This patient Y$_{90}$ reduced to 1.5 GBq after 4.5 days on 9/May Sat late night (4.5 days)
The patient was discharged from isolation ward on Sunday 10/May/15 9:00 am.
An example of isolation room for radiation protection purpose
Another example of isolation room: patient is confined in the room
Isolation room really tight in booking!!! What to do?

- Similar Y90 of about 5 GBq is quite common in TheraSphere
- In this, patient has to be staying in isolation room for about 5 days!!

- If a Centre is without isolation room and SIRT has to be done, what should be done?
- If the isolation room, currently occupied by the SIRT patient, has to be used for other urgent needs, what should be done?
A possible solution & justification:

• by allocating the $^{90}$Y treated patient at a corner bed in a common ward.
• the lead lined blanket is used to cover the radioembolized region.

- The dose rate at 1m is calculated to be 1 μSv/hr (assumed 2.1 GBq infusion).
- Patient separation about 2 m in ward, dose rate at the next patient will be about 0.25 μSv/hr (bkg level in most HKG locations)
- SIRT patient will not expose the next patient significantly.
Patient urine

• No observable Y90 urine content from post Tx WBS (literature quotes very little in the resin spheres for the 1st 24 hours post SIRT; the glass spheres are not known to be present in any body fluid)

• Advise patient to flush toilet twice after use

• In other words, radioembolized patients can use common toilet facility as other non-radiation patients do.
What do we learn from the post Tx scan? Radioactive urine?

- For documentation purpose
- Use bremsstrahlung scan emitted from patient
- Dual head gamma camera using medium energy parallel hole collimators
- Whole body scan and localized abdominal view (conventional gamma camera before and now SPECT/CT)
- **NO OBSERVABLE Y90 IN BLADDER, URINE IS COLD!**
Conclusion for radiation protection in SIRT:

- To understand the basics of Y90, delivery method & patient management procedures
- To understand the personnel concern about radiation in SIRT procedures
- How to prepare for the contamination in IR room
- To understand bremsstrahlung emission from patient
- How to reduce the bremsstrahlung irradiation to personnel
- Personnel dose measurement
- How to apply the radiation protection measure in patient ward
Thank you