SIRT: State of the ART

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Disclosure of speaker’s interests

Consultant for BTG, Sirtex and Terumo

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Radioembolization

- Scout dose
- Treatment
- Discharge

24 hours
Scout dose

• Current gold standard in radioembolization work-up

• Why?
  – Excluding extrahepatic depositions
  – Assessing lung shunting
  – Assessing intrahepatic distribution
Scout dose

- Current gold standard in radioembolization work-up
- Why?
  - Excluding extrahepatic depositions
  - Assessing lung shunting
  - Assessing intrahepatic distribution
Excluding extrahepatic deposition
Excluding extrahepatic deposition

catheter in coeliac trunc

LHA

RHA

GDA
Excluding extrahepatic deposition

Injection position for $^{99m}\text{Tc-MAA}$
CIRSE Questionnaire

60 hospitals, 15 countries
CIRSE Questionnaire

Type of microspheres (in %)

- SIRSpheres (Resin) 40%
- TheraSpheres (Glass) 25%
- Both 35%
Always/most of the time coiled: 2011
Gastroduodenal 71%
Right gastric 59%
Cystic 41%

Powerski, Eur J Rad 2012

It is now generally accepted that preventive, systematic occlusion of the gastroduodenal and right gastric arteries, among others, before any RE is not only needless but also dangerous and even harmful

Bilbao, JVIR 2014
General consensus

Injection positions for $^{99m}$Tc-MAA
Early development of arterial tree

**Embryo**

Jin *et al.*, Liver Transplantation 2008

**Adult liver**

van den Hoven *et al.*, CVIR 2014
## Segmental Hepatic Arterial Vascularization Patterns

<table>
<thead>
<tr>
<th>Type</th>
<th>Originating from the Celiac Axis</th>
<th>Originating from the SMA</th>
<th>Originating from the LGA</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) No aberrant hepatic arteries</td>
<td><img src="image1" alt="Table cells" /></td>
<td><img src="image2" alt="Table cells" /></td>
<td><img src="image3" alt="Table cells" /></td>
<td><img src="image4" alt="Table cells" /></td>
</tr>
<tr>
<td>1a</td>
<td>LHA [2-4] &amp; RHA [5-8]</td>
<td>-</td>
<td>-</td>
<td>73 (66%)</td>
</tr>
<tr>
<td>1b</td>
<td>LHA [2-3] &amp; RHA [4-8]</td>
<td>-</td>
<td>-</td>
<td>51 (46%)</td>
</tr>
<tr>
<td>1c</td>
<td>LHA [2-3], MHA [4] &amp; RHA [5-8]</td>
<td>-</td>
<td>-</td>
<td>21 (19%)</td>
</tr>
<tr>
<td>2) Aberrant left hepatic arteries</td>
<td><img src="image5" alt="Table cells" /></td>
<td><img src="image6" alt="Table cells" /></td>
<td><img src="image7" alt="Table cells" /></td>
<td><img src="image8" alt="Table cells" /></td>
</tr>
<tr>
<td>2a</td>
<td>RHA [4-8]</td>
<td>-</td>
<td>rLHA [2-3]</td>
<td>10 (9%)</td>
</tr>
<tr>
<td>2b</td>
<td>RHA [5-8]</td>
<td>-</td>
<td>rLHA [2-4]</td>
<td>7 (6%)</td>
</tr>
<tr>
<td>3) Aberrant right hepatic arteries</td>
<td><img src="image9" alt="Table cells" /></td>
<td><img src="image10" alt="Table cells" /></td>
<td><img src="image11" alt="Table cells" /></td>
<td><img src="image12" alt="Table cells" /></td>
</tr>
<tr>
<td>3a</td>
<td>LHA [2-4]</td>
<td>rRHA [5-8]</td>
<td>-</td>
<td>15 (14%)</td>
</tr>
<tr>
<td>3b</td>
<td>LHA [2-3]</td>
<td>rRHA [4-8]</td>
<td>-</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>3c</td>
<td>LHA [2-4]</td>
<td>rRHA [4-8]</td>
<td>-</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>3d</td>
<td>LHA [2-3], RHA [4-6-8] &amp; aRHA [5]</td>
<td><img src="image13" alt="Table cells" /></td>
<td><img src="image14" alt="Table cells" /></td>
<td>1 (1%)</td>
</tr>
<tr>
<td>4) Aberrant right and left hepatic arteries</td>
<td><img src="image15" alt="Table cells" /></td>
<td><img src="image16" alt="Table cells" /></td>
<td><img src="image17" alt="Table cells" /></td>
<td><img src="image18" alt="Table cells" /></td>
</tr>
<tr>
<td>4b</td>
<td></td>
<td>rRHA [5-8]</td>
<td>rLHA [2-4]</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>4e</td>
<td>RHA [7]</td>
<td>aRHA [5,6,8]</td>
<td>rLHA [2-4]</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>5) Replaced common hepatic artery</td>
<td><img src="image19" alt="Table cells" /></td>
<td><img src="image20" alt="Table cells" /></td>
<td><img src="image21" alt="Table cells" /></td>
<td><img src="image22" alt="Table cells" /></td>
</tr>
<tr>
<td></td>
<td></td>
<td>LHA [2-4] &amp; RHA [5-8]</td>
<td>-</td>
<td>3 (3%)</td>
</tr>
</tbody>
</table>
Results – unidentified aberrant hepatic arteries

CT

$^{99m}\text{Tc}\text{-MAA SPECT/CT}$

$^{90}\text{Y-PET/CT}$
Practical approach

Pretreatment CT

*Retroportal course*
Aberrant RHA from SMA

*Fissure for lig. venosum*
Aberrant LHA from LGA
Identification of aberrant hepatic arteries (right vs. left)

<table>
<thead>
<tr>
<th></th>
<th>CT</th>
<th></th>
<th></th>
<th>Angiography</th>
</tr>
</thead>
<tbody>
<tr>
<td>abRHA's</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n = 24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>54%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>46%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>abLHA's</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n = 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>44%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>56%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>abRHA's</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n = 24</td>
<td></td>
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</tr>
<tr>
<td>Yes</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>abLHA's</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n = 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>69%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>No</td>
<td>31%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

p = 0.007
Note that the S4A does not fill with contrast agent (arrow) and that the catheter is directed towards the vessel wall.

Post-treatment $^{90}$Y PET/CT scan demonstrates a wedge-shaped lack of activity in tumor-bearing segment 4 (arrow).
Excluding extrahepatic deposition

Accessory left gastric artery coming off the left hepatic artery
Excluding extrahepatic deposition
CIRSE Questionnaire

Reason to use Cone beam CT

- Not used at all: 22%
- Extrahepatic deposition assessment: 52%
- To check tumor coverage: 65%
- For volumetric analysis: 30%
- Other: 3%
Cone beam CT
Scout dose

- Current gold standard in radioembolization work-up

- Why?
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  - Assessing lung shunting
  - Assessing intrahepatic distribution
CIRSE Questionnaire

Percentage of centers that exclude patients because of too high lung-shunt percentage

- **52%** of centers exclude patients with lung-shunt percentage of 0 - 1%
- **28%** of centers exclude patients with lung-shunt percentage of 2 - 5%
- **17%** of centers exclude patients with lung-shunt percentage of 6 - 10%
- **3%** of centers exclude patients with lung-shunt percentage of 11 - 25%
- Less than **3%** of centers exclude patients with lung-shunt percentage above 25%
Percentage of centers that reduce dose because of too high lungshunt percentage

CIRSE Questionnaire

Percentage of centers that reduce dose because of too high lungshunt percentage:

- 0 - 1%: 35%
- 2 - 5%: 45%
- 6 - 10%: 17%
- 11 - 25%: 3%
- > 25%: 0%
Scout dose

$^{99m}$Tc-MAA

Microspheres

20 µm
Lung shunt

Microspheres get stuck arterioles
↓
Shake the $^{99m}$Tc-MAA syringe
↓
Particles break
↓
<10 µm + Free $^{99m}$Tc-pertechnetate
↓
Physiologic shunting!
$^{99m}$Tc-MAA overestimates the lung shunt

$^{99m}$Tc-MAA; 30 Gy

$^{166}$Ho scout dose; 0.02 Gy

$^{166}$Ho treatment; 0.01 Gy

Elschot et al. EJNMMI 2014
Scout dose

• Current gold standard in radioembolization work-up

• Why?
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DOSIMETRY
Radiation absorbed dose matters!

A dominant reason for radioembolization failure!

Wasan et al. Lancet Oncology 2017
BSA-method

1.82 GBq

REILD

1.85 GBq

Progressive disease
Dosimetry is a balancing act!

What is an effective tumor absorbed dose?

What is an acceptable liver absorbed dose?

How do we know?
Validated methodology is needed!
Bilobar treatment from proper hepatic (mCRC)

Baseline PET/CT

CACT: RHA (blue) and LHA (red)

Preferential flow to LHA

Response at 2 m.
Simplicit$^{90}$Y dosimetry software
Personalized radioembolization

<table>
<thead>
<tr>
<th></th>
<th>Average abs. dose</th>
<th>Tumor abs. dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Hepatica sinistra</td>
<td>220 Gray</td>
<td>420 Gray</td>
</tr>
<tr>
<td>A. Hepatica dextra</td>
<td>40 Gray</td>
<td>140 Gray</td>
</tr>
</tbody>
</table>

Patient was additionally treated with an 80 Gray average absorbed dose (yttrium-90 glass microspheres) in the RHA
Dosimetry

One-compartment modeling:
- No differentiation between tumor and non-tumor
- Average absorbed dose in the target volume

Two-compartment modeling:
- Differentiation between tumor and non-tumor
- Average absorbed dose in the tumor (and/or non-tumor)

Voxel based dosimetry:
- Differentiation within the tumor (and non-tumor)
- Dose volume histogram analysis
Pre-treatment scout dose SPECT/CT

Normal liver absorbed dose?
Pre-treatment scout dose distribution
What is the normal liver absorbed dose?

Absorbed dose > 30 Gy

Dose-volume histogram:
Ho deposited in healthy liver tissue

Percentage of healthy tissue

Deposited dose (Gy)

55%

Absorbed dose > 30 Gy
Individualized radioembolization

Scout dose → Treatment → Discharge

24 hours

Dose-volume histogram:
- No deposited in healthy liver tissue

- Percentage of healthy tissue
- Deposited dose (Gy)
Conclusion

- CACT may largely replace SPECT/CT for extrahepatic activity evaluation (know your anatomy!)

- Lung shunt assessment using $^{99m}$Tc-MAA is unreliable

- SPECT-CT scout dose evaluation becomes increasingly important for dosimetry and individualized treatment planning!