^{90}Y-Microsphere Therapy: Emerging Trends and Future Directions

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Manufacturer's Instructions

	TheraSphere®	SIR-Spheres®
Characteristics	~25 µm glass, ~2500 Bq/sphere	~35 µm resin, ~70 Bq/sphere
Indication for use	Hepatocelluar carcinoma	Liver metastases from primary colorectal cancer
Contraindications	Severe liver dysfunction, extrahepatic deposition, high bilirubin, low albumin, portal vein occlusion	Clinical liver failure, extrahepatic deposition, high bilirubin, low albumin, portal vein thrombosis
Lung limits	30 Gy	30 Gy or 20% lung shunt
Dose range	80 – 150 Gy	Typically less than 80 Gy
Activity (GBq) to treat liver lobe	$\frac{[Dose\ (Gy)] * [Mass_{Lobe}\ (kg)]}{50}$	$\left[BSA - 0.2 + \frac{V_{Tumor}}{V_{Lobe}}\right] * \left[\frac{V_{Lobe}}{V_{Liver}}\right]$

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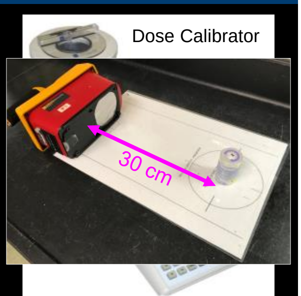
Pre-treatment Measurements

SIR-Spheres®

TheraSphere®

Dose Calibrator



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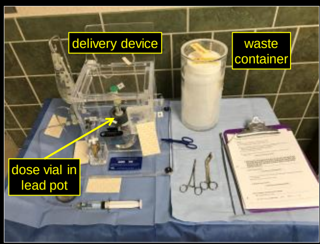
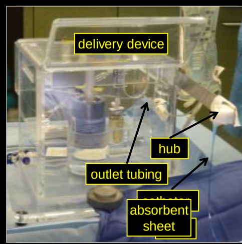
Treatment Setup and Delivery

Treatment Cart



Treatment Delivery



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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

waste container

GM meter

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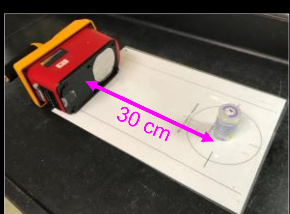
TheraSphere® – Dose Delivery Efficiency

Pre-treatment



Post-treatment

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

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Decay in storage

- 1 month ~ ten ^{90}Y half-lives
- TheraSphere® – small amounts of long-lived radioactive by-products (^{88}Y)

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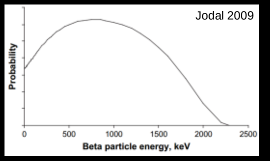
Radiation Safety

- ^{90}Y is β^- emitter
  - Half-life = 2.7 days
  - $E_{\beta^-}^{avg} = 0.93\ MeV,\ E_{\beta^-}^{max} = 2.3\ MeV$
  - 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



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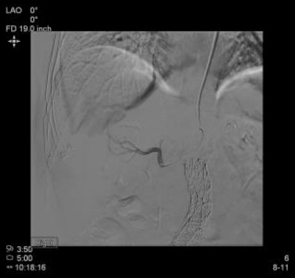
Pre-treatment angiography



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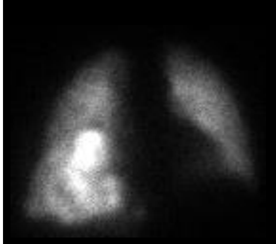
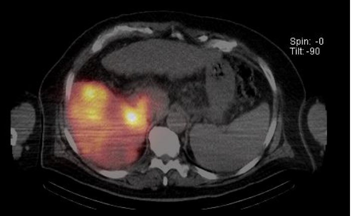
Pre-treatment ^{99m}Tc-MAA Scan



Planar Image



SPECT/CT

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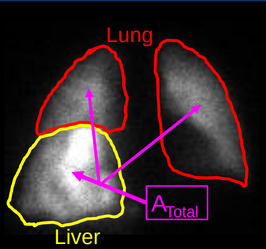
Standard Model

$$A_{Total} = A_{Liver} + A_{Lung}$$

$$LSF = \frac{Lung\ counts}{Lung\ counts + Liver\ counts}$$

$$D_{Lung} = \frac{\left(50\frac{J}{GBq}\right) * \overbrace{A_{Total} * (LSF)}^{A_{Lung}}}{M_{Lung}}$$

$$D_{Liver} = \frac{\left(50\frac{J}{GBq}\right) * \overbrace{A_{Total} * (1-LSF)}^{A_{Liver}}}{M_{Liver}}$$



^{99m}Tc-MAA Scan

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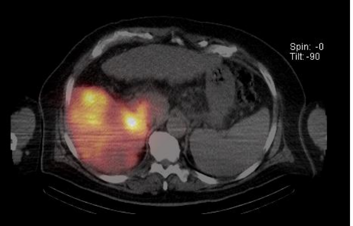
Standard Model

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

^{99m}Tc-MAA SPECT/CT



D_{Lobe} = 120 Gy

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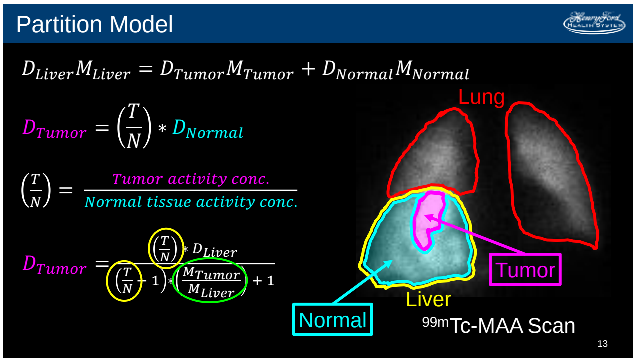
Partition Model
$D_{Liver}M_{Liver} = D_{Tumor}M_{Tumor} + D_{Normal}M_{Normal}$
$D_{Tumor} = \left(\frac{T}{N}\right) * D_{Normal}$
$\left(\frac{T}{N}\right) = \frac{Tumor\ activity\ conc.}{Normal\ tissue\ activity\ conc.}$
$D_{Tumor} = \frac{\left(\frac{T}{N}\right) * D_{Liver}}{\left(\left(\frac{T}{N}\right) - 1\right) * \left(\frac{M_{Tumor}}{M_{Liver}}\right) + 1}$
Lung
Tumor
Liver
Normal
99mTc-MAA Scan
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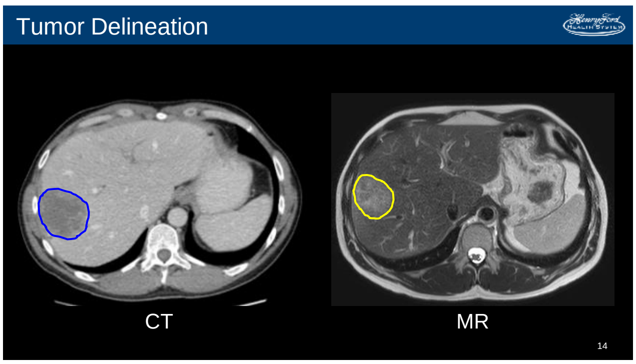
Tumor Delineation
CT
MR
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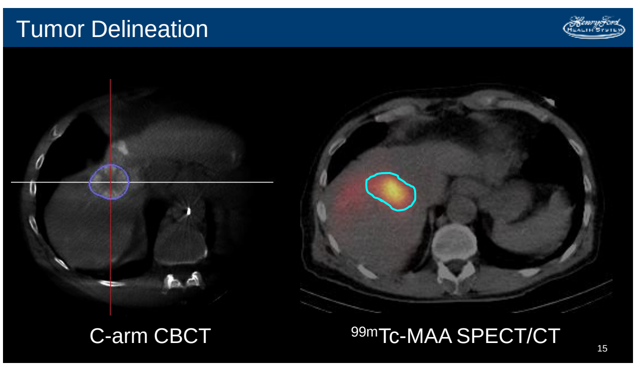
Tumor Delineation
C-arm CBCT
99mTc-MAA SPECT/CT
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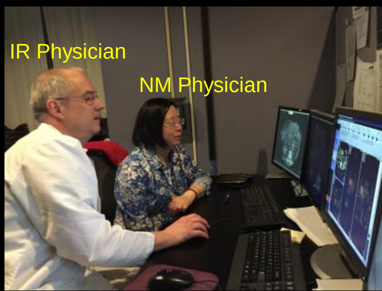
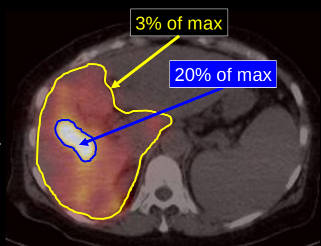
IR/NM Collaboration



T/N Uptake Ratio (Vascularity Ratio)

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



^{99m}Tc-MAA SPECT/CT

Dosimetry depends on model

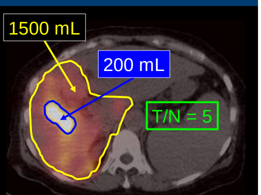
Method	Total Activity	Dose			
		Liver Lobe	Tumor	Normal Tissue	Lung
Standard					
Partition*					
Partition					

*Assume T/N = 3

Standard Model / Partition Model

$$D_{Liver} = \frac{\left(50\frac{J}{GBq}\right) * A_{Total} * (1-LSF)}{M_{Liver}}$$

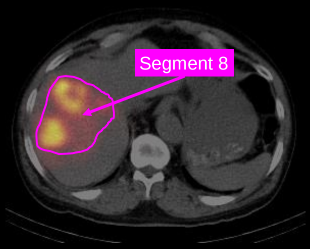
$$D_{Tumor} = \frac{\left(50\frac{J}{GBq}\right)\left(\frac{T}{N}\right) * A_{Lobe} * (1-LSF)}{\left(\frac{T}{N}-1\right) * \left(\frac{M_{Tumor}}{M_{Lobe}}\right) + 1}$$



^{99m}Tc-MAA SPECT/CT

Radiation Segmentectomy

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



^{99m}Tc-MAA SPECT/CT

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Conclusion

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Thank you

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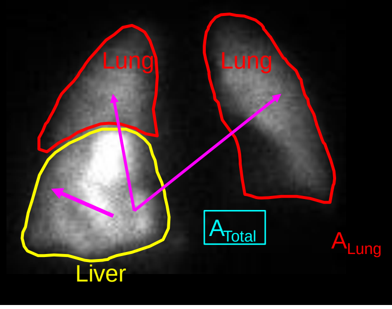
^{99m}Tc-MAA Mapping



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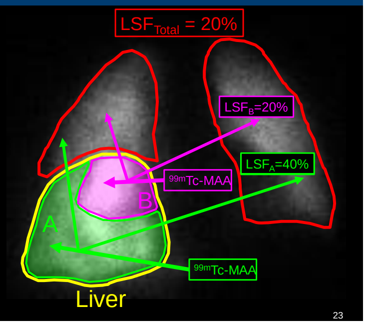
Example

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



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Dosimetry – Partition Model

$$A_{Total} = A_{Lobe} + A_{Lung}$$

$$D_{Lung} = \frac{\left(50\frac{J}{GBq}\right) * A_{Total} * (LSF)}{M_{Lung}}$$

$$D_{Lobe} = \frac{\left(50\frac{J}{GBq}\right) * A_{Total} * (1-LSF)}{M_{Lobe}}$$

$$D_{Tumor} = \left(\frac{T}{N}\right) * D_{Normal}$$

$$D_{Lobe}M_{Lobe} = D_{Tumor}M_{Tumor} + D_{Normal}M_{Normal}$$

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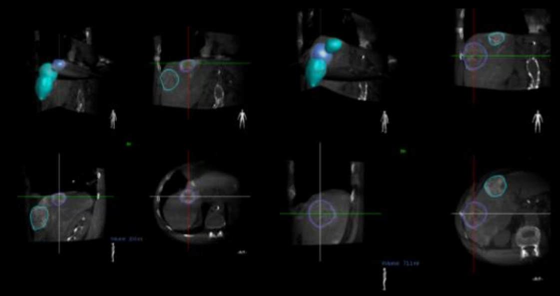
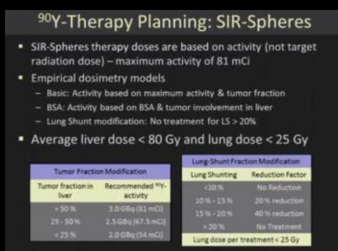
Dosimetry: Tumor and Normal Tissue





^{90}Y-Therapy Planning: SIR-Spheres

- SIR-Spheres therapy doses are based on activity (not target radiation dose) – maximum activity of 81 mCi
- Empirical dosimetry models
  - Basic: Activity based on maximum activity & tumor fraction
  - BSA: Activity based on BSA & tumor involvement in liver
  - Lung Shunt modification: No treatment for LS > 20%
- Average liver dose < 80 Gy and lung dose < 25 Gy

Tumor Fraction Modification	
Tumor fraction in liver	Recommended ^{90}Y-activity
> 50 %	3.0 GBq (81 mCi)
25 - 50 %	2.5 GBq (67.5 mCi)
< 25 %	2.0 GBq (54 mCi)

Lung-Shunt Fraction Modification	
Lung Shunting	Reduction Factor
<10 %	No Reduction
10 % - 15 %	20 % reduction
15 % - 20 %	40 % reduction
> 20 %	No Treatment
Lung dose per treatment < 25 Gy	