Improving Accuracy of Predicted Lung Dosimetry in ^{90}Y-Microsphere Radioembolization with ^{99m}Tc-MAA planar scintigraphy

Benjamin P. Lopez[1], A. Mavash[1], J.P. Long[1], M.G.E.H. Lam[2], S.C. Kappadath[1]

1. The University of Texas MD Anderson Cancer Center, Houston, TX
2. University Medical Center Utrecht, Utrecht, The Netherlands

THE UNIVERSITY OF TEXAS MD Anderson Cancer Center | UTHealth The University of Texas Health Science Center at Houston

Graduate School of Biomedical Sciences

Lung Dosimetry with Scintigraphy

Radiation pneumonitis (RP) is a rare, but serious, complication after ^{90}Y-microsphere radioembolization of liver cancers

Microspheres are shunted from the liver and embolize the pulmonary vasculature, depositing dose in lung tissue

To minimize the risk of **RP**, commercial products (SIR-Spheres[1] and TheraSphere[2]) define procedures for predicting the **Lung Dose (LD)** by estimating **Lung Shunt Fraction (LSF)** and **Lung Mass (LM)**

Estimating LD with Planar Scintigraphy: Standard Practice

1. Administer ^{99m}Tc-macro-aggregated albumin (^{99m}Tc-MAA) at site of expected ^{90}Y-microsphere administration
2. Acquire anterior and posterior views of the chest and abdomen with a gamma camera
3. Estimate **LSF** from image counts

$$LSF = \frac{(Lung\ Counts)}{(Lung\ Counts) + (Non - Lung\ Counts)}$$

4. Estimate **LD** from **LSF**, **LM**, and the planned ^{90}Y administered activity (A_{90Y})

$$LD\ [Gy] = 49{,}670 \left[\frac{Gy \cdot g}{GBq}\right] \times \frac{LSF}{LM[g]} \times A_{90Y}[GBq]$$

Goal: Improving Lung Dosimetry

^{99m}Tc-MAA SPECT/CT-based dosimetry is known to more accurately estimate true **LM** & ^{90}Y-microsphere **LSF** & **LD** (*See Lopez 2019*)

However, **Standard-of-Care (SOC)** in many clinical centers still relies on ^{99m}Tc-MAA planar scintigraphy for treatment planning

In this work, we assessed the accuracy and potential clinical impact of different approaches to planar-based dosimetry in comparison to SPECT/CT-based dosimetry

Goal: Make recommendations for improved accuracy in planar-based **LSF** and **LD** estimations

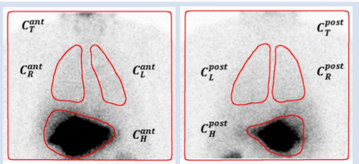
Methods: Planar LSF Analysis

For each of the 46 patients who underwent ^{99m}Tc-MAA planar and SPECT/CT imaging for treatment planning, we calculated:

Gold-Standard SPECT/CT LSF = **Using expanded liver counts and liver-shine-through corrected lung counts (*Lopez 2019*)**

6 Possible Planar LSFs = **3 Views** Anterior, Posterior, Geometric Mean * **2 Contours** Lungs & Liver, Lungs & Total

Example contours used to calculate left (C_L) and right (C_T) lung, liver (C_H), and total frame (C_T) counts in anterior (C^{ant}) and posterior views (C^{post}). Total lung counts defined as $C_{LR} = C_L + C_R$.



The **Recommended Planar LSF** was determined through 2 metrics

Accuracy: Absolute difference relative to SPECT/CT LSF

Clinical Impact: Percentage of cases where the planar LSF could have limited the potential ^{90}Y-microsphere dose prescription (i.e., LSF > 10%)

Methods: Planar LD Analysis

For each of the 44 patients who proceeded to receive ^{90}Y-microsphere therapy, we calculated **LD** using the actual $A_{90Y}[GBq]$

Gold-Standard SPECT/CT LD = **Using SPECT/CT LSF and patient-specific LM from diagnostic CT densitovolumetry (*Lopez 2019*)**

4 Possible Planar LDs = **2 Planar LSF** SOC Geo. Mean, Best (See Above) * **2 Lung Masses** 1,000 g, Patient-Specific

The **Recommended Planar LD** was defined as the approach with smallest absolute difference from SPECT/CT LD

Results: Recommended Planar LSF, LM, and LD Calculations

Recommended Planar LSF: $(LSF)^{ant}_{LR,H}$

Planar LSF Calculations		Absolute Error in LSF		Cases with LSF > 10%
View	Equation	Median	(95% Range)	
ANT	$(LSF)^{ant}_{LR,H} = C^{ant}_{LR}/C^{ant}_{H}$	0.028	(0.003 – 0.044)	6%
	$(LSF)^{ant}_{LR,T} = C^{ant}_{LR}/C^{ant}_{T}$	0.024	(0.002 – 0.034)	12%
POST	$(LSF)^{post}_{LR,H} = C^{post}_{LR}/C^{post}_{H}$	0.056	(0.013 – 0.100)	40%
	$(LSF)^{post}_{LR,T} = C^{post}_{LR}/C^{post}_{T}$	0.040	(0.008 – 0.070)	31%
GEO	$(LSF)^{geo}_{LR,H} = \frac{\sqrt{C^{ant}_{LR} \times C^{post}_{LR}}}{\left(\sqrt{C^{ant}_{LR} \times C^{post}_{LR}} + \sqrt{C^{ant}_{H} \times C^{post}_{H}}\right)}$	0.045	(0.012 – 0.059)	27%
	$(LSF)^{geo}_{LR,T} = \frac{\sqrt{C^{ant}_{LR} \times C^{post}_{LR}}}{\sqrt{C^{ant}_{T} \times C^{post}_{T}}}$	0.034	(0.009 – 0.044)	12%

In general, the most accurate planar **LSF** values were calculated using only anterior view contours

In our cohort, the **LSF** overestimation using **SOC** $(LSF)^{geo}_{LR,H}$ may have unnecessarily limited ^{90}Y administration in ~25% of cases

We caution using total frame counts to estimate **LSF** as these may include extra-hepatic MAA distribution that would not occur following ^{90}Y-microsphere administration

Gold-Standard SPECT/CT Values[3]

	Median	(95% Range)
LSF	0.02	(0.00 – 0.11)
LM (g)	816	(548 – 1,172)
LD (Gy)	3.0	(0.3 – 22.4)

Recommended Planar LD: $(LSF)^{ant}_{LR,H}$ & 1,000g LM

Planar LD Calculations		Absolute Error in LD (Gy)	
Planar LSF	Lung Mass	Median	(95% Range)
$(LSF)^{ant}_{LR,H}$	1,000 g	1.7	(-1.2 – 9.7)
	Patient-Specific	2.6	(0.3 – 14.7)
$(LSF)^{geo}_{LR,H}$	1,000 g	3.6	(0.7 – 14.7)
	Patient-Specific	5.0	(1.2 – 20.7)

In general, the most accurate planar **LD** values were calculated using the anterior view **LSF** values

Although the 1,000 g **LM** assumption overestimated most patient-specific **LM** estimations (*see gold-standard values above*), using patient-specific values with planar **LSF** values actually increased planar **LD** errors

Final Recommendations

Recommended Lung Dosimetry $LD\ [Gy] = 49{,}670 \left[\frac{Gy \cdot g}{GBq}\right] \times \frac{LSF}{LM[g]} \times A_{90Y}[GBq]$

Lung Shunt Fraction: Use counts from lungs and liver contours of the anterior view

Lung Mass: Use standard-man 1,000 g

Additional Considerations

Future work is necessary to assess the impact, if any, of:

- Image acquisition parameters
- User contour variability & auto-segmentation tools

Planar dosimetry approaches here were only compared to ***PLANNING*** SPECT/CT ^{99m}Tc-MAA dosimetry but ***NOT*** to ***ACTUAL DELIVERED*** ^{90}Y-microsphere dosimetry

References

[1]. Sirtex Medical Limited. [Online].
[2]. Biocompatibles UK Ltd. [Online].
[3]. Lopez et al. Med Phys, 46(9), 3929–3940. 2019.

Kappadath Lab – The University of Texas MD Anderson Cancer Center, Houston, TX
S. Cheenu Kappadath, Ph.D.
Associate Professor, Department of Imaging Physics
URL: http://www.mdanderson.org/kappadath-lab
Email: skappadath@mdanderson.org
Phone: 713-745-2835