บทความวิจัย

Evaluation of Lung Shunt Fraction from Planar Scintigraphy and SPECT/CT Images

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Abstract

Evaluation of a lung shunting fraction using ^{99m}Tc macro-aggregated albumin (MAA) scintigraphy is required to simulate the distribution pattern of the ^{90}Y therapeutic activity for radio-embolization treatment of liver malignancies. The purpose of this study was to compare lung shunt fraction evaluated from planar scintigraphy and SPECT/CT imaging to ensure that the administered activity of ^{90}Y microspheres will not cause serious complication to the lungs. Lung shunt fraction (LSF) from ^{99m}Tc MAA pre-therapeutic planar scintigraphy and SPECT/CT imaging of 33 hepatocellular carcinoma patients were retrospectively analyzed. LSF from planar scintigraphy was calculated based on ROI counts from lung and liver images by combining the anterior and posterior images using the geometric mean. For SPECT/CT imaging, LSF was quantified from the count in volume of interest in liver and lung. The LSF estimated from planar imaging was statistically significant ($p = 0.000$) when compared to the LSF derived from SPECT/CT imaging. It was almost 2 times higher in all cases as compared to SPECT/CT. The mean ± SD of lung shunt fraction (%) on planar and SPECT/CT imaging in 33 patients were 10.62 ± 7.88 and 6.87 ± 7.20, respectively. ^{90}Y microspheres treatment requires accurate planning to ensure a good therapeutic response with as less complications as possible. Detecting the liver and tumor with planar images can be difficult and lead to misinterpretation of possible extrahepatic locations because of the low spatial resolution from planar images. ^{99m}Tc-MAA imaging is used to estimate the LSF prior to 90Y treatment. The assessment of LSF with planar imaging was significantly overestimate LSF compared to SPECT/CT, possibly from activities originating in overlying and underlying tissue from organ overlapping in 2D images. Calculation by SPECT/CT can then be considered as more accurate because it gives the true representation of 3D organs.

Key word: Hepatocellular carcinoma, ^{99m}Tc MAA scintigraphy, ^{90}Y radioembolization, Lung shunting fraction

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Introduction

Hepatocellular carcinoma (HCC), also called malignant hepatoma, is a primary malignancy of the liver and the most common type of liver cancer. HCC has variable grade of vascularity according to the histological tumor grade and underlying liver damage.

Radioembolization is an innovative therapeutic approach defined as the injection of micron-sized embolic particles loaded with a radioisotope by use of percutaneous intra-arterial techniques. Advantages of the use of these intra-arterial radioactive compounds are the ability to deliver high doses of radiation to small target volumes, the relatively low toxicity profile, the possibility to treat the whole liver including microscopic disease and the feasibility of combination with other therapy modalities.

Yttrium-90 (^{90}Y) microspheres are commonly used for hepatic radioembolization. As ^{90}Y microspheres become trapped within the small feeding capillaries of the tumor, they deliver high radiation doses to the tumor with minimal toxicity to normal liver tissues [1]. Before therapeutic administration of ^{90}Y microspheres to the patient, radioactive ^{99m}Tc-labeled macroaggregated albumin (MAA) was injected into the main hepatic artery to mimic the distribution of ^{90}Y microspheres and to ensure safety of the procedure.

In assessing the risk of extrahepatic deposition of microspheres, ^{99m}Tc MAA scan, planar and SPECT/CT images are performed to detect any uptake of ^{99m}Tc MAA outside of liver, particularly in the lungs and gastrointestinal tract. The intrahepatic tracer distribution and tumor-to-normal uptake ratio (TNR) are important for dose calculation especially when using a partition model or BSA method. A good correlation between the estimated radiation dose by ^{99m}Tc MAA dosimetry and intraoperative estimation of radiation doses have been reported in several publications [2-7].

The lung shunt fraction (LSF) is defined as the ratio of radioactive counts in the lungs to the combined radioactive counts in the lungs and liver. Significant error in ^{90}Y microsphere treatment dose did occur if the ROIs or VOIs were not defined properly in the lung shunting calculation [8].

The purpose of this study was to compare lung shunt fraction calculated from planar scintigraphy and SPECT/CT imaging to ensure that the administered activity of ^{90}Y microspheres will not cause serious complication to the lungs.

Materials and methods

A. Materials

SPECT/CT scanner: All imaging were performed on a Discovery NM/CT 670. SPECT/CT, a dual-modality imaging system that provides functional (SPECT) and anatomic (CT) images in the same scanning session. The scanning modes include planar mode and tomographic mode.

B. Selection of study population

Planar and SPECT/CT images of ^{99m}Tc MAA were acquired in 33 patients with HCC and had the basis of typical computed tomography (CT) criteria before radioembolization.

C. Lung shunt calculation procedure

Image processing and analysis were performed on a GE workstation to calculate the percentage of lung shunt.

1. Drawn regions of interest (ROIs) manually around the whole lungs and the whole liver on both anterior and posterior views of the planar images (Figure 1).
2. Drawn volume of interest (VOIs) on SPECT/CT imaging using the dosimetry toolkit application (Figure 2).
3. Get the total counts for the lungs and the liver from ROIs and VOIs.
4. Calculate geometric mean (GM) for lung and liver regions on the planar images.
5. Calculate the percentage of lung shunting.

For planar image, 2-dimensional lung and liver regions of interest and total ^{99m}Tc MAA counts are obtained. Lung shunt fraction (LSF) is calculated as the fraction of the activity counts from the whole lungs divided by counts in the lungs and liver combined using the following formula;

$$\%LSF = \frac{GM_{Lung}}{GM_{Lung} + GM_{Liver}} \times 100$$

Where; GM_{Lung} and GM_{Liver} are the geometric means of the counts from the lung and liver respectively. Geometric means are calculated from the anterior and posterior counts as:

$$\square\square = \sqrt{\square\square\square\square\square\square_{\square\square\square} \times \square\square\square\square\square\square_{\square\square\square\square}}$$

For SPECT/CT image, 3-dimensional, the dosimetry toolkit software allows semiautomatic generation of the VOIs in the lung and liver.

$$\%LSF = \frac{Lung\ Counts}{Lung\ Counts + Liver\ Counts} \times 100$$

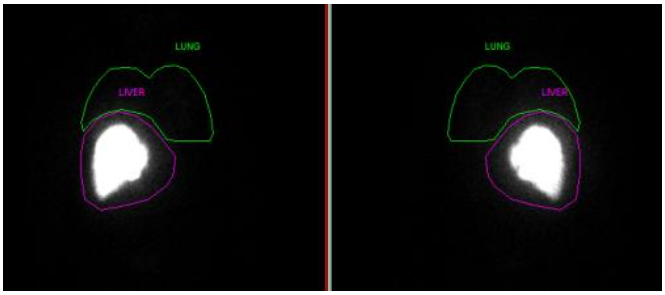

Fig. 1 Manually draw the ROIs of ^{99m}Tc MAA infusion and distribution from anterior and posterior views on the planar images.

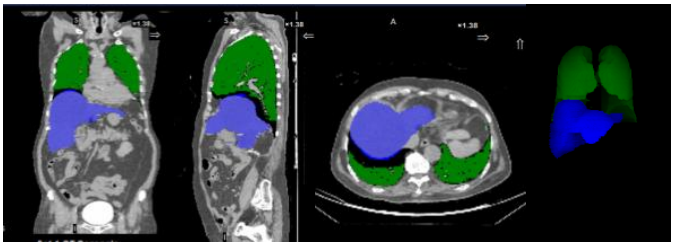

Fig. 2 The VOIs on SPECT/CT images using the dosimetry toolkit application.

Results

Images of 33 patients; 25 men (76%) and 8 women (24%) with hepatocellular carcinoma (HCC) demonstrated lung shunt factions ranging between 2.04 to 29.73% in planar images and 0.20 to 31.95% in SPECT/CT images. The mean ± SD of lung shunt fractions (%) on planar and SPECT/CT images were 10.62 ± 7.88 and 6.87 ± 7.20, respectively. A significant difference between the planar and SPECT/CT lung shunt fractions (%) was observed (p=0.000). Lung shunt fraction distribution is shown in table 1.

According to the package insert of SIR-Spheres, if the calculated LSF is below 10% then therapy will proceed at the standard dose, LSF of 10.0 to 14.9% requires an activity reduction of 20%, an LSF of 15% to 20% requires 40% reduction, and an LSF of greater than 20% is regarded contraindication against radioembolization.

Table 1 A comparison between lung shunt fractions calculated from planar and SPECT/CT images.

No.	Sex	% Lung Shunting	
		Planar	SPECT/CT
1	M	7.67	3.00
2	F	14.07	17.40
3	M	3.82	0.90
4	M	6.41	3.37
5	M	29.73	20.77
6	M	13.68	7.50
7	M	10.04	4.50
8	M	9.50	5.60
9	M	3.62	1.24
10	F	3.31	1.25
11	M	9.33	4.60
12	M	7.76	3.20
13	M	3.54	1.52
14	M	4.04	1.28
15	M	2.98	0.80
16	M	7.17	2.70
17	M	4.94	2.20
18	F	6.17	2.50
19	M	2.04	0.20
20	F	18.43	14.00
21	M	28.42	14.40
22	M	21.38	13.80
23	F	24.84	18.10
24	M	3.51	0.30
25	M	8.12	5.89
26	M	13.44	8.20
27	F	13.18	7.30
28	M	4.44	1.50
29	F	25.62	31.95
30	M	6.30	5.90
31	M	6.07	6.89
32	F	8.97	4.30
33	M	17.87	9.60
Mean		10.62	6.87
SD		7.88	7.20
Min		2.04	0.20
Max		29.73	31.95
P-value			0.000

Discussion

^{99m}Tc MAA imaging is important in treatment planning to avoid significant radiation pneumonitis from lung shunting. ROIs should be accurate and consistent to reduce error in calculating the treatment dose.

Planar scintigraphy is a 2D anatomic image, and thus it is difficult to delineate the lung and liver accurately. The problem is further compounded by the motion of the liver due to the patient's breathing during

the acquisition, which tends to blur the border between the lung and liver on planar scintigraphy.

Uncertainties in defining ROIs are due to the limited spatial resolution of the planar imaging in combination with human error in drawing the regions. Tomographic imaging will improve accuracy in the lung shunt calculation. The current method for calculating lung shunting factions is subjective and does not allow for quantification of lung uptake as it is planar (2D) based. It does not incorporate corrections for photon attenuation and scattering, both of which are significance in quantification by planar imaging and cannot accurately represent dose distribution [9] and absorbed dose values cannot be found from such measures.

The radioembolization simulation procedure is logistically challenging, as the patient has to be injected within the interventional radiology department and scan within 1 hour to prevent false-positive extrahepatic activity due to free ^{99m}Tc pertechnetate. In such cases, pathologic uptake in the stomach should be ruled out before treatment. Free ^{99m}Tc is normally observed in SPECT/CT as diffuse uptake in the gastric mucosa, often in concordance with the thyroid gland on planar imaging, whereas pathologic uptake is seen as a focally increased accumulation [10, 11].

Conclusion

The lung shunt calculation base on planar images substantially overestimates the lung shunt in most cases. For patients with significant lung shunt from planar images, a careful study of the lung shunt base on the SPECT/ CT is warranted for a more accurate result.

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