Research Article

Lung Shunt Estimate in Yttrium-90 Microsphere Therapy

Jianqiao Luo

Department of Radiology, Virginia Commonwealth University Healthcare Systems, Richmond, Virginia, USA

Corresponding author: Jianqiao Luo, Department of Radiology, Virginia Commonwealth University Healthcare Systems, P.O. Box 980001, Gateway 236, 1200 East Marshall Street, Richmond, Virginia 23298-0001, USA, Tel: +1 8048281443; Fax: +1 8048284181; E-mail: jianqiao.luo@vcuhealth.org

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Abstract

This study was to evaluate lung shunting from Tc-99m MAA (Macroaggregated Albumin) and Y-90 imaging, and its effect on treatment planning. Y-90 Microspheres (Therasphere, BTG) were selected for this study. Y-90 Sirsphere (SirTex) is similar in term of lung shunt estimate. Tc-99m MAA imaging is utilized to assess pulmonary shunting which will affect treatment dose. Uncertainty or inaccuracy of the shunting calculation using Region of Interest (RoI) definition may be significant caused by drawing the RoIs on clinical images. Standard shunting compares the ratios of activity in the liver and lungs.

Introduction

Yttrium-90 MicroSpheres have been used for the treatment of unresectable Hepatocellular Carcinoma (HCC) [1]. Tc-99m MAA imaging is performed to assess extra hepatic flow to the pulmonary shunting, which is a key factor in treatment planning. The maximum allowed dose to the lungs for a single treatment is 30 Gy [2,3]. The Tc99m MAA was to simulate Y-90 microspheres in order to evaluate distribution and shunting before the actual therapy to avoid lung injury from Y-90 radiation. There are two types of Y-90 microspheres: Therasphere (BTG) and Sirspheres (SirTex) used for liver cancer. Y-90 Microspheres (Therasphere, BTG) were selected for this study. Tc-99m MAA imaging is utilized to assess pulmonary shunting which will affect treatment dose. Standard shunting compares the ratios of activity in the liver and lungs.

Treatment planning of Y-90 Therasphere is based on liver volume and shunting ratio. The recommended dose to the liver is between 80 Gy to 150 Gy [2,4]. The liver volume and mass is determined from CT scan, or could be from SPECT imaging as well. Since the Therasphere dose is normally shipped in a few preset quantities: 3, 5, 7 GBq etc., actual dose depends on patient scheduling to account for radioactive decay. Unlike in Sirsphere treatment procedure, there is no dose preparation (or dose draw) on the user side. However, measurement of the Therasphere dose with dose calibrator and ion chamber should be performed carefully because of the nature of Y-90 emission of beta particle.

Methods

Twenty-five HCC patients were randomly selected to evaluate shunting ratios with Tc-99m MAA infusion, prior to their Y-90 Therasphere treatments. Eight studies required the redrawing of RoIs (Region of Interest) to correct the variance in geometric mean. Actual activity was determined following treatment planning guidelines based on standard and measured shunting. Y-90 imaging of patients was also investigated for radionuclide distribution.

Microspheres Pre-treatment Imaging [4,5].

<table>
<thead>
<tr>
<th>Radiopharmaceutical</th>
<th>Tc-99m Macroaggregated Albumin (MAA)</th>
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<tbody>
<tr>
<td>Dose</td>
<td>4 mCi (total volume - QS to 2 ml)</td>
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<tr>
<td>Route of Administration</td>
<td>Hepatic Catheter infusion</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>Dual-head LFOV SPECT camera with Low energy high-resolution collimators.</td>
</tr>
<tr>
<td>Acquisition Protocol</td>
<td>Acquire a Planar/SPECT study of the liver using the MAA injection.</td>
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</table>

Planar imaging of anterior and posterior views of the chest (for both lungs) and abdomen (for the liver and gastroduodenal region) were acquired with the patient in a supine position. SPECT imaging can be used to estimate the lung shunt ratio with high accuracy and specificity but longer imaging time and more work on tomographic volume definition.

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Image processing and analysis were performed on a Siemens workstation to calculate the percentage of lung shunt. Regions of interest were drawn manually around lungs and liver on the planar images (Figure 1). For each study, ROIs were drawn on the images of the lung-fields in the anterior and posterior views (excluding the heart) (Figure 2 and 3). Likewise, ROIs were drawn around the liver on both anterior and posterior views. The geometric mean of the net anterior and posterior count rates was calculated for both of lungs and liver. The lung shunt was calculated as the ratio of lung counts to total counts; the ratio of the lung counts and the summed counts in the lungs, liver and tumor [5].

Inadequate ROIs were identified in 8 patients (Table 1), which yielded up to 5% (mean 0.79%, STD 1.76%) difference (p=0.90) in lung shunting. The treatment dose showed 5.29% (mean 0.74%, STD 2.21%) deviation (p=0.91) caused by the ratios. It was further compared with standard ratios of 4% for none-HCC and 7% for HCC.

Difference in the treatment doses from corrected ratios and the standard was: mean 9.01%, STD 19.7%, p=0.19 for the 4% and mean 5.18%, STD 19.0%, p=0.55 for the 7%. Y-90 patients’ images did not provide activity distribution in lungs when there was high shunting based on Tc99m MAA imaging, but demonstrated Y-90 activity in liver.

Tc99m MAA imaging is important in treatment planning to avoid error from lung shunting. ROIs should be accurate and consistent to reduce error in treatment dose.
Y-90 imaging depends on scatter characteristic of tissue and does not yield appropriate shunting images with Yttrium-90.

**Results**

- Inadequate ROIs were identified in eight patient images, which yielded up to 5% difference in lung shunting ratios.
  - Avg. 0.79%
  - STD 1.76%
  - t Test: p = 0.90
- The treatment dose showed 5.29% deviation caused by the ratios.
  - Avg. 0.74%
  - STD 2.21%
  - t Test: p = 0.91
- Results were further compared with standard ratios of 4% for non-HCC and 7% for HCC.
  - Avg. 9.01%, STD 19.7%, t Test: p = 0.19 for the 4%
  - Avg. 5.18%, STD 19.0%, t Test: p = 0.55 for the 7%
- Nuclear medicine imaging using Tc\textsuperscript{99m} MAA is an important part of treatment planning.
- Significant error occurs if the standard lung shunting is used in dose calculation.
- In Tc\textsuperscript{99m} MAA image analysis, ROI analysis should be accurate and consistent in order to reduce possible error in treatment dose.

There are uncertainties in defining ROIs due to limited special resolution of the gamma camera and human error in drawing the regions. Tomographic imaging will improve the lung shunt calculation, and SPECT CT technology should be used to obtain volume of interest counts to evaluate activity ratios.

**References**