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Assessment of Residual Activity from Yttrium-90 Microsphere Therapy using Bremsstrahlung Imaging

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Abstract

Objective: To estimate distribution of Yttrium-90 glass spheres and evaluate long-lived radioactive contaminants in Y-90 Therasphere (BTG) therapy using gamma camera Bremsstrahlung imaging. Post therapy distribution of the microspheres is to validate the infusion of the Y-90 microspheres and to provide information for more accurate dosimetry compared with the dose estimate based on uniform distribution assumption. The post therapy imaging is also one of the methods to measure the long half-life contaminants.

Method: Thirty days post-therapy patient images were acquired to assess Yttrium-90 distribution after 1.9 GBq Y-90 microspheres were infused through the Theraspheres radioembolization procedure. A Siemens eCam dual head camera was employed with MEGP collimators, 20% energy window centered at 120 keV for a 20 minute-whole body scan. An anthropomorhic torso phantom was either filled with water or left empty in its tank and 70% of total 0.35 GBq Y-90 in liver, 15% in right (wet) and left lung (dry) respectively. The Same camera with HEGP collimators was setup to 364 keV, 20% window, 128X128, 20 minutes acquisition time at different energy window settings.

Results: Bremsstrahlung images of the Anthropomorhic torso phantom did not change significantly with collimators but with energy windows. Images of the phantom showed more activity in the wet lung than the dry. TherasSpheres patient's images did not show Y-90 uptake in the lungs whereas the Tc-99m MAA scan showed significant uptake. Distribution of Y-90 glass spheres in liver could be identified but not shown clearly because of Compton scattering and collimator penetration. Bremsstrahlung image were obtained from the remaining 0.86 MBq Y-90 left in the patient body (30 days physical decay of Y-90).

Conclusion: Y-90 microsphere distribution can be imaged using gamma camera as an estimate. Accurate description of the distribution is still a challenge to current imaging modalities although PET scan has shown some improvement Radioactive contaminants (Eu-152, Eu-154 and Y-88) were not detected by the gamma camera due to their high energy of gamma rays and low level of activity.

Introduction

Yttrium-90 is widely used in radionuclide therapy due to its excellent physics properties:

Max. E(Beta) = 2.284 MeV; Avg. E(Bata) = 0.93 MeV; Half-life = 2.67 days (64.1 hours)

Max. Beta range in water = 1.1 cm, Max. Beta range in air = 1,062 cm.

Figure 1 describes the Bremsstrahlung X-ray distribution and Figure 2 shows an actual Bremsstrahlung X-ray spectrum acquired from a gamma counter.

Y-90 microspheres are infused through a catheter into the fine branching blood vessels and stopped in capillary tubes that the spheres cannot move through [1]. A significant amount of radiation dose (80 to 120 Gy, [2] is delivered to the tumor to kill the cancer cells. Y-90 has a half-life of 64.1 hours. The T-heraspheres sample had measurable amounts of the following radionuclides: Y-88(half-life 107 days); Europium-154 (half-life 8.8 years); Europium-152 (half-life 13.6 years); Cobalt-57 (half-life 270.9 days); and Cobalt-60 (half-life 5.27 years). Those long-half-life contaminants deliver limited radiation dose to patients but generate environmental protection issues [3].

Since Y-90 is a pure beta emitter, it is not possible to detect those beta particles after infusion since most of the betas will be absorbed by tissue. However, the Bremsstrahlung X-rays generated by those beta particles' interaction with tissue can be detected. One way to image the distribution of the beta particles is

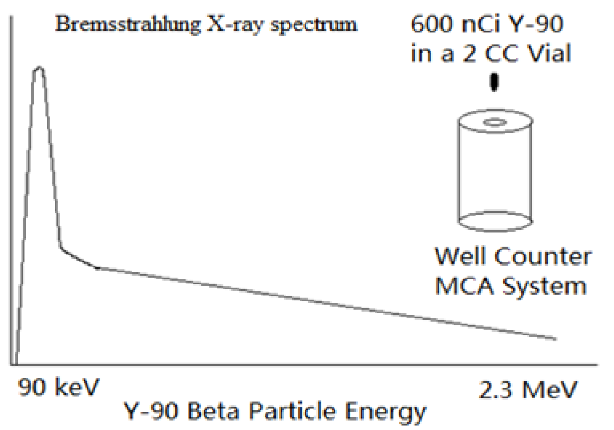

Figure 1: Description of the Bremsstrahlung X-ray distribution and measurement using multichannel analyzer.

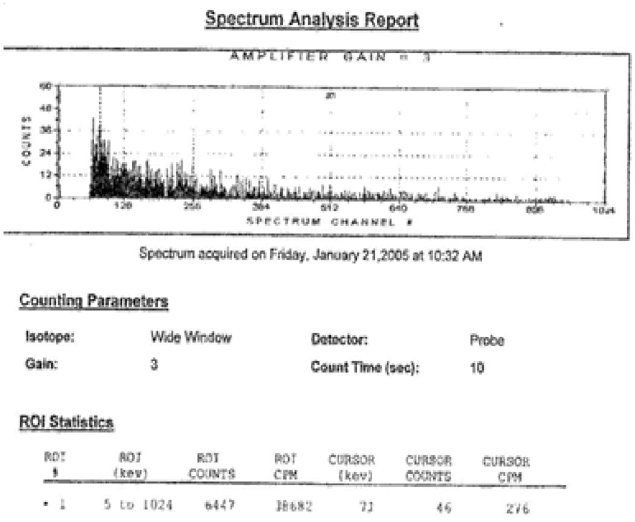

Figure 2: shows an actual Bremsstrahlung X-ray spectrum acquired from a gamma counter with MCA.

to detect Bremsstrahlung X-rays. Energy of the Bremsstrahlung X-rays spreads out to 2.3 MeV, which is much higher than a gamma camera can image. Collimator penetration of high energy X-rays is the major problem. However, using a gamma camera to estimate Y-90 microsphere distribution and may be one of the options in some clinical cases. PET imaging of coincidence photons demonstrates a better image, and should be used when it is available.

Radioactive contaminants: Eu-152 (half-life 13 years); Eu-154 (half-life 8.6 years) and Y-88(half-life 107 days) in microspheres are environmental concerns due to their long half-life and various emissions from radioactive decays. Gamma camera imaging is used to evaluate amount of residual activities and distributions after the Y-90 microsphere therapy and long-term effects.

Phantom studies were performed to evaluate distribution of the

Figure 3: Set up of the anthropomorhic torso phantom, and gamma camera protocol.

Y-90 microspheres. Figure 3 describes the setup of the anthropomorhic torso phantom.

Phantom studies were performed to test various acquisition protocols and patient imaging was to evaluate Y-90 image characteristics on human samples. An anthropomorhic torso phantom was filled with water or left empty in its tank and 70% of total 0.35 GBq Y-90 in liver, 15% in right (wet) and left lung (dry) respectively. A Siemens eCam dual head camera with HEGP (360 keV) collimators was setup to 364 keV, 20% window, 128X128, 20 minutes acquisition time at different energy window settings. Other energy settings were also tested.

A modified Jaszczak phantom was also scanned to test images of cold spheres in Y-90 water tank. Patient images of Yttrium-90 distribution after 1.9 GBq in microscopic glass spheres installed through the Theraspheres radioembolization procedure were acquired using MEGP collimators, 93/184/300 keV windows. A Zevalin patient was scanned 30 minutes post injection of 3.66 GBq Y-90 using MEGP collimators, 75 keV window.

Images of the anthropomorhic torso phantom showed more activity in the wet lung than the dry lung. Images of the Jaszczak phantom did not yield any structure.

There is no significant difference between images from MEGP and HEGP collimators since Bremsstrahlung X-ray of Y-90 can be up to 2.28 MeV. Energy window settings changed image quality and 75 keV/50% demonstrated better images than other energies. Imaging Y-90 glass spheres could yield information about distribution of the spheres but was not adequate for lung shunting estimate [4]. Figure 4 shows the images from the gamma camera scan of anthropomorphic torso phantom.

Figure 6 Bremsstrahlung images of the Anthropomorhic Torso phantom did not change significantly with collimators but with

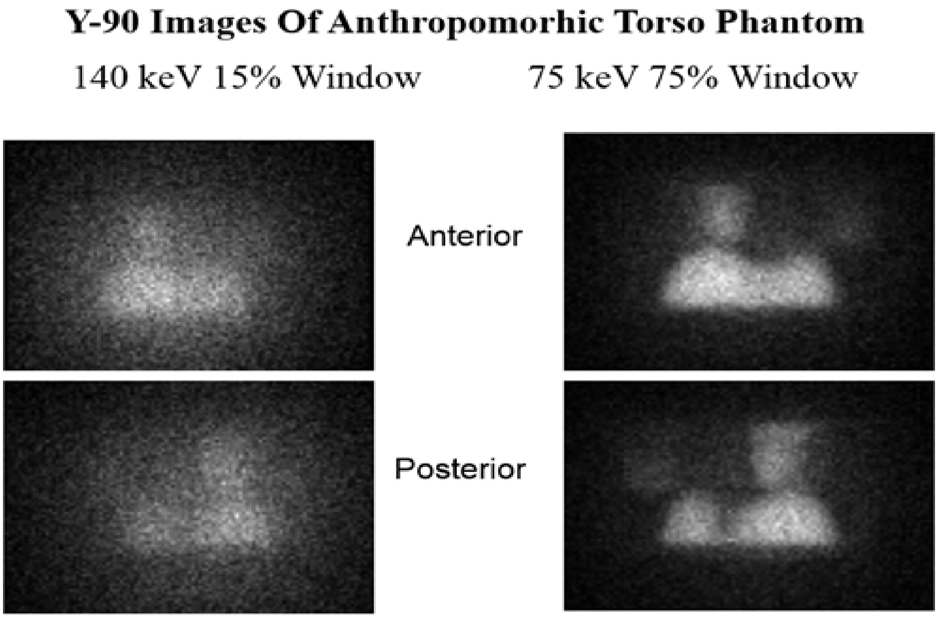

Figure 4: Images from the gamma camera scan of anthropomorhic torso phantom.

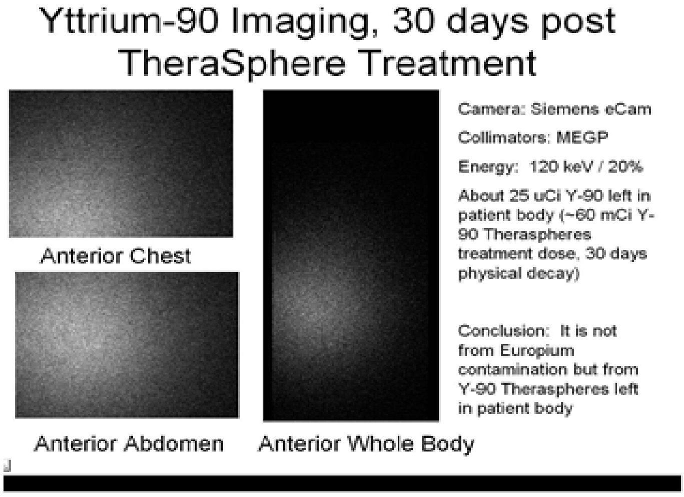

Figure 5: The images from the gamma camera scan of patient after the Y-90 Therasphere treatment.

energy windows. The collimator penetration depends on photon energy. When imaging Y-90 produced Bremsstrahlung, the penetration is significant throughout most part of the energy spectrum. Images of the phantom showed more activity in the wet lung than the dry lung due to the production of Bremsstrahlung in the wet lung.

Theraspheres images did not show Y-90 uptake in the lungs whereas the Tc-99m MAA scan showed significant uptake. This could be due to low imaging efficiency for Y-90 than for Tc99m. Distribution of Y-90 glass spheres in liver could be identified but not shown clearly because of Compton scattering and collimator penetration. Bremsstrahlung images were from 0.86 MBq Y-90 left in patient body (30 days physical decay of Y-90). Radioactive contaminants (Eu-152, Eu-154 and Y-88) were not detected by gamma camera due to their high energy of gamma rays and low level of activity.

As initial investigation of the Y-90 distribution and evaluation of low level, long half-life radioactive contaminations, the gamma camera can be used in some cases. However, PET imaging has demonstrated its ability to generate high quality images compare to most gamma camera scans. However, both imaging modalities detect indirect emission of photons that are not beta rays. Therefore, the images may not accurately describe the distribution of the beta particles and labeled compounds.

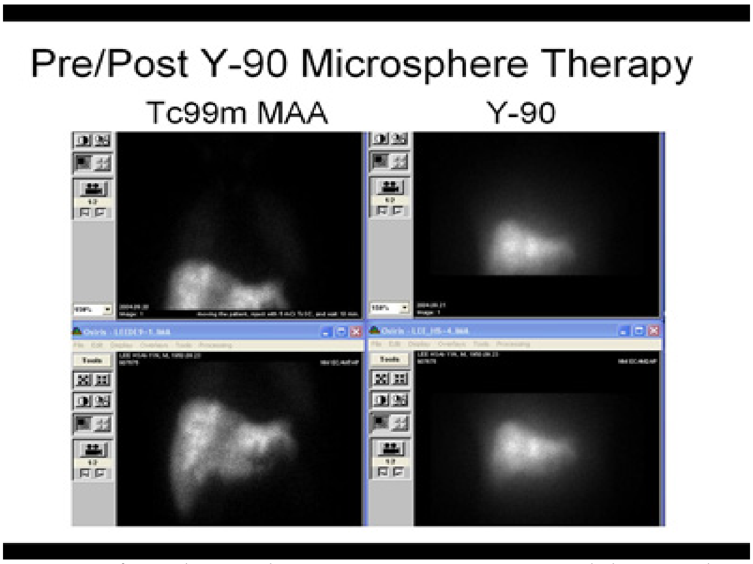

Figure 6: Compare images from the pre-therapy Tc-99m MAA scan and the post-therapy Y-90 Therasperes imaging.

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