Effect of Technetium-99m on a Computerized Tomography Scan

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We compared the photon fluence of 20 mCi of Tc-99m to the x-ray photon fluence found in a computerized tomography scan. Diagnostic radionuclide activities of Tc-99m used in nuclear medicine are found to have a negligible effect on the information content of a CT scan.

We investigated the effects of such nuclear medicine procedures as brain imaging on the accuracy of a transmission computerized tomography scan. We were attempting to answer the often raised question of whether or not the injection of approximately 20 mCi of Tc-99m for a brain scan interferes with the data obtained in a CT scan. One may expect that a volume containing 20-mCi Tc-99m generates a reduced linear attenuation coefficient in a CT scan, thereby lowering the CT number and the effective density of the volume. To investigate these radionuclide effects we performed a calculation using a simple model of 20 mCi of Tc-99m centered in a head phantom to determine the relative number of radionuclide and x-ray photons that reach a detector in a CT scanner/sec.

Theory

The geometry of the calculation is that of the Ohio Nuclear Delta 50 Fast Scan II, with x-ray source and crystal detector 105 cm apart. Centered in this region is a 20-cm diameter water phantom containing a small volume of 20-mCi Tc-99m at the geometrical center. We determined the number of x-ray and gamma, Tc-99m, photons/sec intercepted by a detector. Self-absorbtion effects are neglected.

The x-ray photon fluence through a 20-cm diameter water phantom reaching a single detector is calculated from the monoenergetic photon exponential attenuation equation:

$$N_1 = N_o e^{-\mu x} \qquad \text{(Eq. 1)}$$

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where N_o is the number of incident photons, N_1 is the number of transmitted photons, μ is the linear attenuation coefficient of the medium, and x is the thickness of the attenuator. The incident x-ray beam, 150 kVp, has an effective energy of 69.5 keV (*1*). N_1 is determined using the following data from McCullough (*2*). For the 140-kVp beam the photon fluence through 20 cm of water is 1.15×10^7 photons/cm^2-mA-sec at 91.4 cm from the x-ray source. Applying the inverse square correction the fluence becomes 8.71×10^6 photons/cm^2-mA-sec. Correcting for air attenuation (*3*) and for an x-ray current of 35mA, the photon fluence, N_1, received by a detector with surface area of 2.38 cm^2 and 100% counting efficiency is 7.24×10^8 photons/sec. A similar calculation for N_o yields 6.35×10^{10} photons/sec.

For the above configuration the photon fluence reaching a single detector from a 20-mCi source of Tc-99m located at the center of the water phantom is calculated as follows. Twenty mCi of Tc-99m emits 6.5×10^8 photons/sec. With no attenuation the number of photons/sec intercepted by a detector is:

$$N = 6.5 \times 10^8 \frac{\text{photons}}{\text{sec}} \times \frac{\text{Area of detector}}{\text{area of sphere (centered on Tc-99m)}}$$

$$= 6.5 \times 10^8 \frac{\text{photons}}{\text{sec}} \times \frac{\pi \left(\frac{1.74}{2}\right)^2}{4\pi(52.5)^2} = 4.46 \times 10^4 \frac{\text{photons}}{\text{sec}}. \qquad \text{(Eq.2)}$$

However, these photons are attenuated by 10-cm water and 42.5-cm air. Thus N_2, the number of emission photons/sec that reach a single detector, is given by

$$N_2 = 4.46 \times 10^4 \frac{\text{photons}}{\text{sec}} e^{-1(1.555)(10)-(1.82 \times 10^{-4})(42.5)}$$

$$= 0.94 \times 10^4 \frac{\text{photons}}{\text{sec}}. \qquad \text{(Eq. 3)}$$

Though the model used in this calculation is not clinically accurate in that approximately 10% of the injected Tc-99m concentrates in the head, the volume of concentration is not negligibly small, and the concentration is not necessarily at the center of the head and may actually be near the surface; this model does, however, provide a reasonable upper limit of radionuclide photon fluence reaching the CT detectors. A comparison of the flux of Tc-99m photons from a 20-mCi source with x-ray photons reveals a discrepancy of almost five orders of magnitude. Thus, the effect of a diagnostic activity of Tc-99m on the reconstructed CT image is negligible.

The accuracy of routine in vivo CT number determination is better than ± 5 *(4)*. Using this criterion for significant variation in CT number, an activity of 26 Ci would be required to effect a significant error in CT number.

References

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