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Estimation of Absorbed Dose for Nonuniformly Distributed I-131 in Tumor

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Abstract

In internal emitter radiotherapy nonuniform activity distributions in geometrically irregular tumor volumes will be encountered. The conventional and established methodology for calculating the absorbed dose requires that individual source regions be uniform activity distribution. Any general dosimetry system should be able to account for the effects of tissue inhomogeneities. I-131 can eradicate small foci of remnant tissue in patient with differentiated thyroid cancer. In this study we present Monte Carlo simulation to evaluate detailed absorbed dose distributions in a homogeneous medium for any given activity distribution of I-131. Results are presented for the dose distribution in a 1 ml target volume with activity distribution which is uniform, limited by diffusion into target volume.

1. Introduction

Current methods for calculating the absorbed dose in a target region from source region rely on a standard geometry and assume an uniform activity distribution. These techniques do not provide estimated to normal tissue dose from activity in the tumor and do not include the contribution to tumor dose from activity in normal tissues. The purpose of this study is to calculate absorbed dose for nonuniform source distribution using Monte Carlo EGS4 code.

2. Methods

The dose rate distribution $D(r)$, produces by a nonuniform activity concentration, $C(r_s)$, in a homogeneous target volume is given by

$$D(r) = \Delta \int_{source\ volume} C(r_s)\, \Phi(|r - r_s|)\, d^3 r_s$$

where $\Phi(r)$ is the point isotropic specific absorbed fraction of the energy emitted by the source that is absorbed per unit mass of medium at a distance r from the source, and Δ is the mean energy emitted per nuclear transformation. For beta dose in homogeneous soft tissue, $\Phi(r)$ was separated into two terms as the fraction of energy absorbed from a primary, essentially unscattered beta-ray component and the fraction of energy absorbed from scattered components of the particles. The Monte Carlo EGS4 code was used to calculate the absorbed dose. Five beta components of I-131(as shown in Table 1) were considered. The beta point isotropic specific absorbed fractions for the components were evaluated individually and were then summed together with weightings equal to the relative abundance of the components. The dose due to the 364 keV photons of I-131 was not included because of its small contribution relative to the beta dose.

I-131 beta emitters	
End point energy (MeV)	Mean energy (MeV)
0.248 (2.1%)	0.069
0.304 (0.6%)	0.087
0.334 (7.4%)	0.097
0.606 (89.4%)	0.192
0.807 (0.4%)	0.283

Table 1. Parameter values used to calculate beta doses in unit density tissue

3. Results

Figures 1 shows, the distribution of radiation dose rate in soft tissue of unit density resulting from a radially symmetrical activity concentration. The result shows a maximum dose rate 95% of radiation equilibrium dose rate for activity concentration 1 MBq/ml. The dotted curve represents the activity distribution. And dose rate falls off very rapidly outside the target volume. Radiation dose in spherical targets of about 1 ml in volume having I-131 distribution was 1.73 Gy/h. In Fig.2. and Fig.3., diffusion of activity into the target volume results in a nonuniform activity distribution. Thus, as expected, the resultant dose rate distributions are nonuniform, especially when low energy beta emitters are used. If there is a constant rate of loss of activity from the target volume, the activity and resultant dose distributions are even more nonuniform.

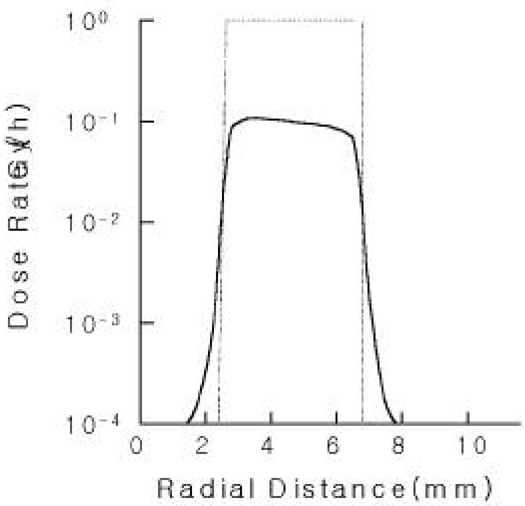

Fig.1. Distribution of radiation dose rate(continuous line) in soft tissue of unit density resulting from a radially symmetrical activity concentration.

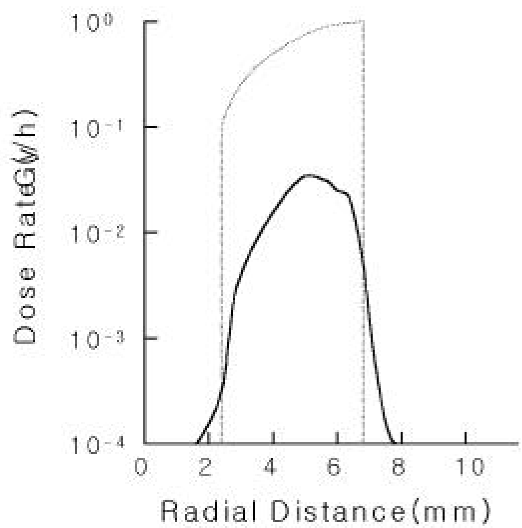

Fig.2. Distribution of radiation dose rate resulting from the nonuniform activity distribution

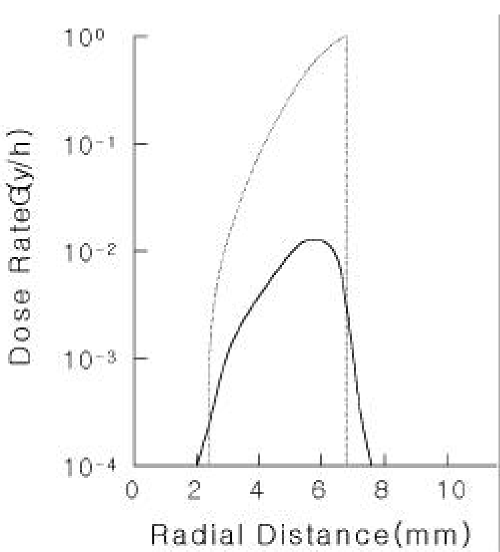

Fig.3. Distribution of radiation dose rate resulting from the nonuniform activity distribution

4. Discussion

In this study we have addressed a simple but important aspect of the dosimetry that will be required to calculate absorbed doses to tumors and adjecent normal tissues due to nonuniformly distributed activities occurring in radiotherapy. Although the most tumors have soft tissue composition, the neighboring normal tissues may include air and bone with very different mass densities and attenuation coefficients. So the additional studies are in progress to extend the complex densities voxel dosimetry.