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CELLULAR DOSIMETRY FOR RADON PROGENY ALPHA PARTICLES IN BRONCHIAL TISSUE

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INTRODUCTION

Inhaled radon progeny are deposited in different regions of the human bronchial tree as functions of particle size and flow rate. Following deposition and mucociliary clearance, the sensitive bronchial basal and secretory cells are irradiated by two different alpha particle sources: (i) radon progeny in the sol and/or gel phase of the mucous layer, and (ii) radon progeny within the bronchial epithelium.

In the case of internally deposited radionuclides, direct measurement of the energy absorbed from the ionizing radiation emitted by the decaying radionuclides is rarely, if ever, possible. Therefore, one must rely on dosimetric models to obtain estimates of the spatial and temporal patterns of energy deposition in tissues and organs of the body. When the radionuclide is uniformly distributed throughout the volume of a tissue of homogeneous composition and when the size of the tissue is large compared to the range of the particulate emissions of the radionuclide, then the dose rate within the tissue is also uniform and the calculation of absorbed dose can proceed without complication. However, if non-uniformities in the spatial and temporal distributions of the radionuclide are coupled with heterogeneous tissue composition, then the calculation of absorbed dose becomes complex and uncertain. Such is the case with the dosimetry of inhaled radon and radon progeny in the respiratory tract.

There are increasing demands to obtain a definitive explanation of the role of alpha particles emitted from radon daughters in the induction of lung cancer. Various authors have attempted to evaluate the dose to the bronchial region of the respiratory tract due to the inhalation of radon daughters (e.g. Altshuler et al., 1964; Haque, 1967; Harley and Pasternack, 1972; Hofmann, 1982; Hofmann et al.,1990; James, 1987; Al-Affan and Haque, 1989).

COMPUTATIONAL METHOD

To evaluate the dose received by the respective populations of secretory or basal target cells from each decay of ^{218}Po or^{214} Po, it is necessary to represent the positions of the source and the targets by a geometrical model. The geometry of each bronchial or bronchiolar airway is approximated by a cylindrical tube. In the model, the inner surface of the tube is considered to be lined by a thin layer, or sheath, of fluid representing mucous ("gel phase"). This inner sheath of mucous is separated from the underlying epithelium by a band of hair-like cilia, which are responsible for clearing the mucous in the direction of the trachea. The cilia are bathed in an aqueous fluid that forms a second, thin layer of shielding material ("sol phase"). Both fluid layers have the protective effect of absorbing some of the energy from radon progeny alpha particles.

Both secretory and basal cells in the bronchial epithelium and, to a lesser extent, secretory cells in the bronchioles were identified as the principal target cells for lung cancer induction. The location and volumetric densities of these cells, provided by Mercer et al. (1991), were used in the present work to evaluate cell-specific doses.

An analytical method has been developed to compute the local energy deposition of ^{218}Po and ^{214}Po alpha particles in 1 μm spheres located at different depths in bronchial epithelium. In order to reach the target, alpha particles travel either through tissue alone ("near wall dose") or through air and tissue ("far wall dose").

A computer program has been written, which, firstly, computes the dose within the epithelium at different depths (that is at different layers supposing that all activity is homogeneously distributed along the surface

of the epithelium or of the mucous layer) and, secondly, it calculates the dose in these layers by supposing that the activity is distributed in these layers. The distribution of the activity among these layers is characterized by weighting factors. For the computation of doses from radionuclides within the bronchial epithelium, two assumptions have been made: (i) nuclides are either uniformly distributed ("uniform case"), or (ii) they decrease linearly with depth in tissue ("linear case"). Then a "realistic distribution" was defined as 70% of activity is in the mucous layer and 30% of it is within the epithelium.

RESULTS

Figure 1 shows the comparison of near wall, far wall, and total (i.e., near + far wall) dose for the ^{214}Po distribution in mucous and epithelium. It can be seen that the contribution of the near wall is higher than that of the far wall as fewer alpha particles will reach the target from the far wall.

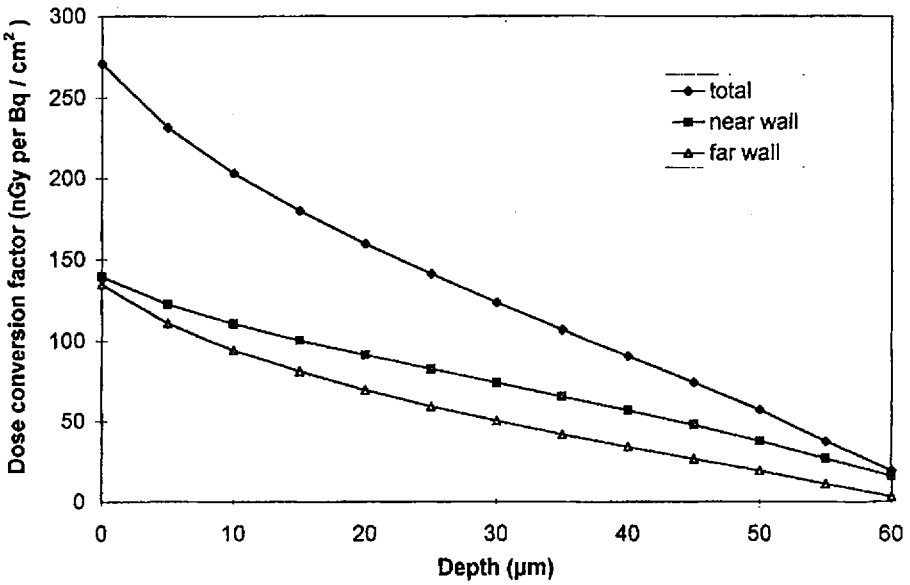

Fig. 1: Comparison of near wall, far wall and total dose in airway generation 4 for a realistic distribution of ^{214}Po nuclides in mucous and epithelium.

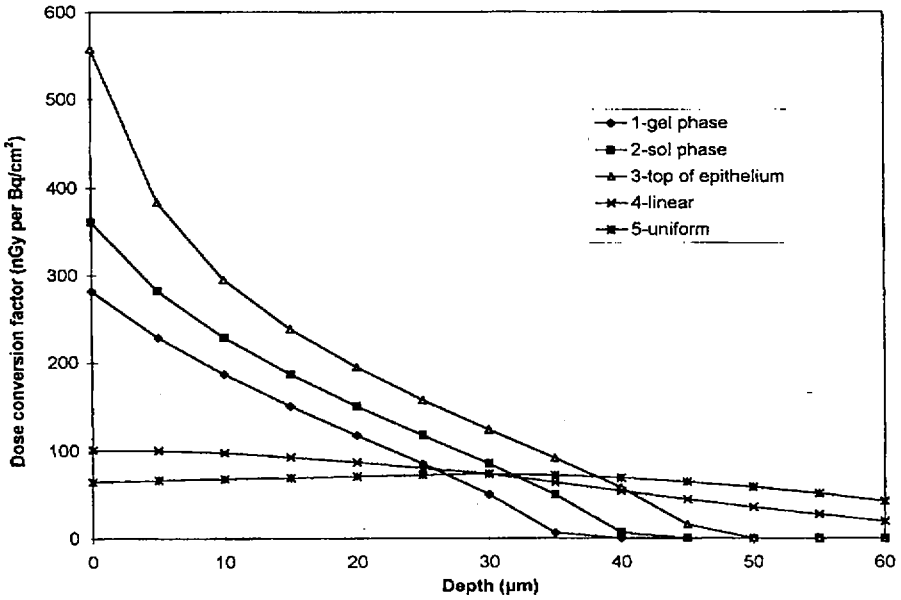

Fig. 2: Total (near + far wall) dose in airway generation 4 for ^{218}Po nuclides: comparison of surface distribution (mucous, cilia, and boundary) with volume distribution (linear, uniform).

Figure 2 displays the variation of dose with depth in bronchial epithelium for ^{218}Po nuclides in airway generation 4: curves 1-3 represent the doses calculated for the nuclide distributed at the top of gel phase layer, sol phase layer, and epithelium, respectively. It can be seen that the dose decreases rapidly with increasing depth. In contrast, however, the same number of alpha particle decaying from radon progeny located in the epithelium (linear and uniform case) produces a relatively constant dose throughout the tissue (curves 4-5).

In addition, cell-specific dose calculations have been performed considering the location and volumetric distribution of basal and secretory cells (Mercer et al., 1991). Figure 3 represents the cell-specific doses as a function of depth in bronchial epithelium for ^{218}Po nuclides in airway generation 4: the cell-specific dose has a maximum at a depth of 30 μm for basal cells and at 25 μm for secretory cells, caused by the difference in the distribution of basal and secretory cells.

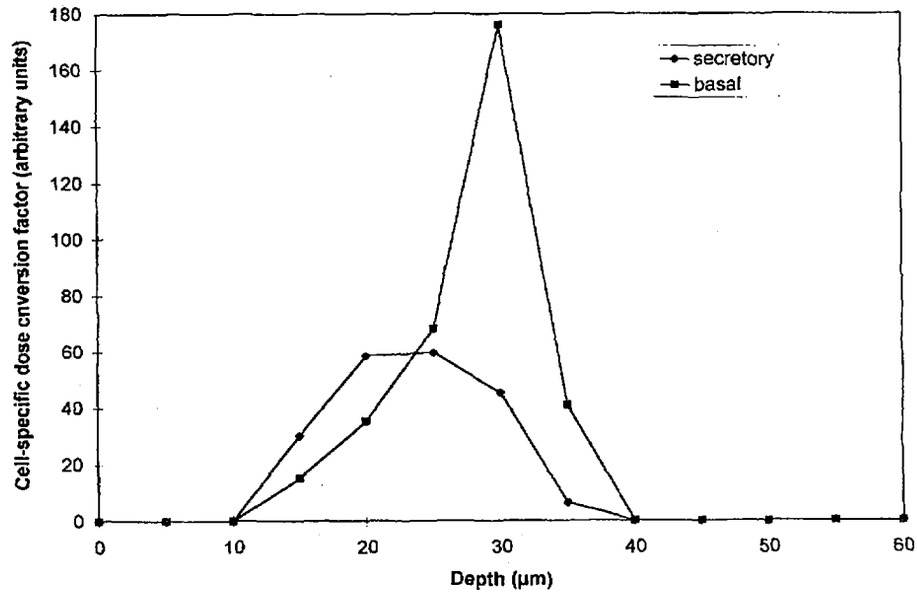

Fig. 3: Cell-specific dose conversion factors for basal and secretory cell nuclei as functions of depth in epithelial tissue produced by ^{218}Po nuclides.

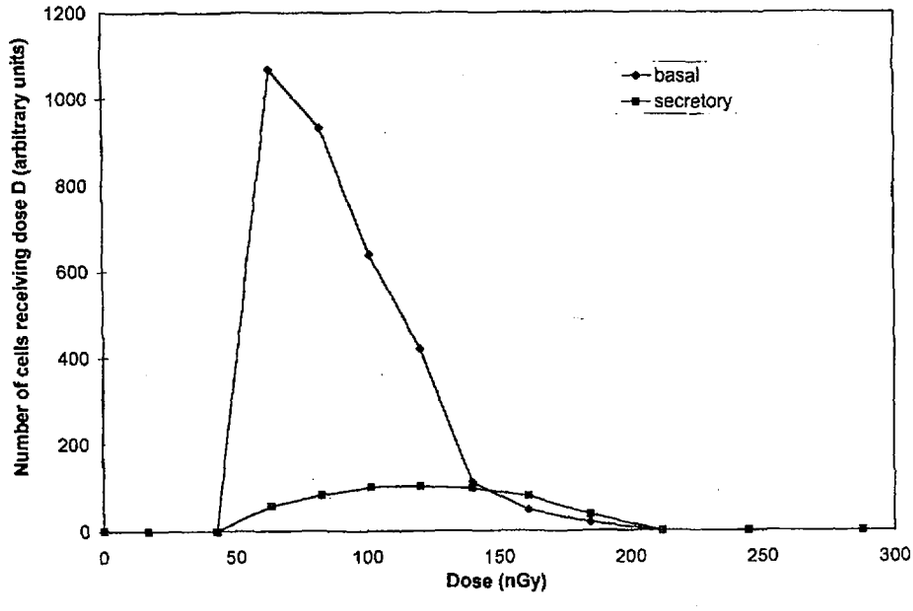

Fig. 4: Distribution of secretory and basal cell doses in airway generation 4 for ^{214}Po nuclides.

Figure 4 shows the distribution of doses in secretory and basal cells for ^{214}Po alpha particles in airway generation 4. Considering their relative frequencies at a given depth in tissue, the mean dose is 120 nGy for secretory cells and 64 nGy for basal cells.

ACKNOWLEDGMENTS

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