THE REVISED INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP) DOSIMETRIC MODEL FOR THE HUMAN RESPIRATORY TRACT

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ABSTRACT

A task group has revised the model of the respiratory tract recommended by the ICRP for use in radiation protection dosimetry[1]. The revised model can be used to project respiratory tract doses for workers and members of the public from airborne radionuclides and to assess past exposures. Doses calculated for specific extrathoracic and thoracic tissues can be adjusted to account for differences in radiosensitivity and summed to yield two values of dose for the respiratory tract that are applicable to the ICRP tissue weighted dosimetry system.

INTRODUCTION

The dosimetric model currently used by the ICRP[1] to estimate doses from inhaled radioactive particles was published in 1966[2]. During the past 25 years, research has yielded new knowledge relevant to modeling the intake, deposition, and clearance of inhaled particles and gases. Also, the needs of the ICRP have expanded well beyond those that can be addressed by the current model. This led to an ICRP Task Group* being asked to develop a revised model.

FEATURES OF MODEL

The model is based on the premise that large differences in radiation sensitivity of respiratory tract tissues and the doses they receive from inhaled radioactive particles and gases argue for calculating doses to specific tissues. The current model[1,2] leads to calculation of doses averaged over the mass of blood-filled lungs.

Parameters needed to calculate doses are assigned values for the reference worker and members of the public. However, values relevant to individuals and to specific exposure situations can be used in the model. Guidance is provided for adjusting the model to account for the possible influence of smoking, respiratory tract diseases, and exposure to airborne toxic substances.

The model is useful for assessment of doses from inhaled radioactive particles and gases as well as for calculating limits on intakes. Tissue average doses calculated for defined regions of the respiratory tract can be adjusted to account for radiation sensitivity differences to yield a single value for the extrathoracic and another value for the thoracic region.

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These two values of dose are applicable to the ICRP tissue weighted dosimetry system for calculating effective dose.

MORPHOMETRIC MODEL

For purposes of modeling, the respiratory tract is represented by five regions identified on the basis of their respiratory function, cytology, and what is known or can be measured with reasonable confidence about the deposition and clearance of inhaled particles and gases. The two extrathoracic regions are the anterior nasal passages (ET_1) and the posterior nasal and oral passages including the mouth, larnyx, and pharynx (ET_2) with associated lymphatics (LN_{ET}). In the thorax are the bronchial (BB), bronchiolar (bb), and alveolar-interstitial (AI) regions with associated lymphatics (LN_{TH}).

For calculating radiation doses, the cytology and histology, as well as morphometric structures, are modeled for each region. Reference values for dimensions important for dose calculations are specified.

DEPOSITION

In modeling the deposition of airborne particles, inhalability and each region of the respiratory tract are represented by a series of equivalent particle filters. The extrathoracic tissues are represented by two filters, one for inhalation and the other for exhalation. The deposition efficiency of each region of the respiratory tract is evaluated by considering particle deposition by aerodynamic and thermodynamic processes, acting competitively. It is assumed that the reference worker is a nose breather, shifting to 50% mouth breathing at respiratory rates greater than about 2.1 m^3h^{-1}.

To model deposition in the extrathoracic airways, an empirical approach based directly on experimental data was used. To evaluate regional deposition, a theoretical model of particle deposition and gas transport was weighted empirically to fit the mean of experimental data.

CLEARANCE OF INHALED MATERIALS

The model describes three clearance pathways (Figure 1). Material deposited in the ET_1 region is removed by extrinsic processes, such as nose blowing. For the other regions, clearance is competitive between particle transport processes (such as macrophage uptake and ciliary action to the G.I. tract and to lymph nodes) and absorption into blood. The rate of clearance by each process is a time-varying factor of the residual amount. It is assumed that the rates of clearance by particle transport are the same for all materials. Rates were derived from studies with human subjects.

Absorption into blood is a two-stage process: dissociation of the particles into material that can be absorbed into the blood (dissolution) and absorption into blood of inhaled soluble

material and of material dissolved from particles. Absorption is material-specific and is assumed to act in all regions except region ET_1. The model can use observed absorption rates of compounds for which reliable human or experimental animal data exist. In the absence of such data, absorption rates are specified as "fast" F, "moderate" M, or "slow" S, based on the current D, W, and Y classification system of the ICRP[2]. The default values, expressed as half-times, are: 10 min for F materials, which are rapidly absorbed into blood; 3 d for 50% and 100 d for the remaining 50% of M materials with intermediate rates of absorption; and 7000 d for S materials, which are very insoluble.

DOSIMETRIC MODEL FOR GASES AND VAPORS

The model addresses three classes of gases and vapors. The first, SR-0, insoluble and nonreactive, results in exposure of all airways. The second, SR-1, either soluble or reactive, results in exposure of all airways. However, these gases and vapors can also be absorbed into tissues and blood throughout all airways. The third class, SR-2, consists of highly soluble and reactive gases and vapors that are completely absorbed by tissues and blood in the extrathoracic tissues.

CALCULATION OF TISSUE AVERAGE DOSES

Doses are calculated by the ICRP system in which energy absorbed is averaged over the mass of the target tissues in each region. These doses can be adjusted to account for differences in radiation sensitivity and summed separately for the extrathoracic and thoracic regions. These two adjusted doses can be used with the ICRP tissue weighting factors in calculations of effective dose[3].

It is proposed that the doses calculated for each region be adjusted on the basis of the best estimates of their relative sensitivity to radiation-induced cancer. These estimates and the factors used to adjust regional doses cannot be very precise because of the scarcity of information and of unknowns such as the influence of smoking and exposure to air pollutants. However, the impact on the summed doses is not large.

SUMMARY

The new respiratory tract model provides for calculating average doses to specific tissues rather than to the total lung mass. The model is more complex than the current model because it describes deposition of inhaled radioactive material in and clearance from several tissues and regions of the respiratory tract and is applicable to the worldwide population of both workers and the public.

REFERENCES

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ACKNOWLEDGMENT

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT DE-AC06-76RLO 1830

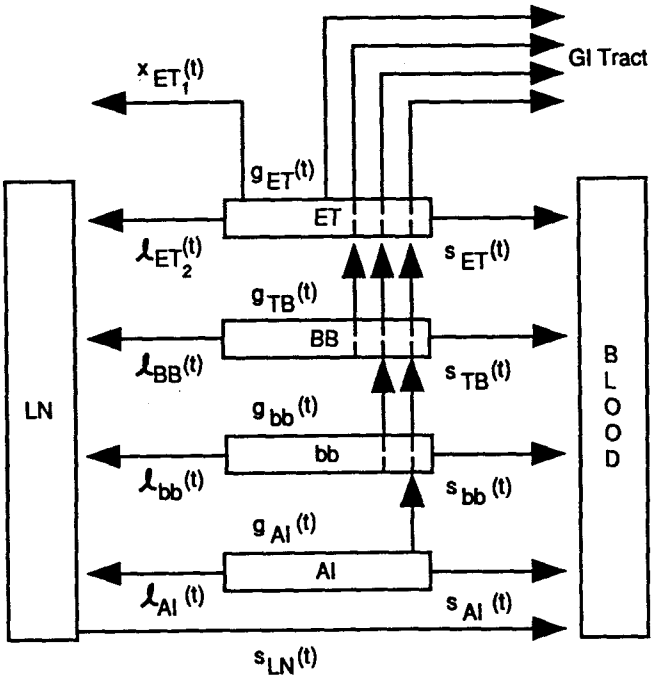

Figure 1. Clearance Model. Symbols indicate fractional rates of clearance, at time t. after an acute intake, by each route from each region.