MATHEMATICAL CONVALIDATION OF BIOKINETIC MODEL FOR ^{131}I PROPOSED BY ICRP 67

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RESUMEN

La implementación del modelo que simula el radio-yodo bioquinetico, propuesto por la Comisión Internacional de la Protección Radiológica (ICRP), permite el cálculo de las actividades en órganos y las excretas del cuerpo humano después de ingerir la sustancia radiactiva. Uno de los más importantes órganos es la tiroides, porque, tiene un gran absorbción de este material, y la orina como medio principal de la excreción, los cuales son de interes en programas de monitoreo para los individuos que tienen riesgo de la incorporación cuando están trabajando con esta sustancia. Hemos utilizado los valores propios y el método del vector propio para obtener las fracciones de la actividad en órganos y las excretas, usando Matlab 7.0. Los números de desintegraciones fueron obtenidos en cada compartimento para 131I que atendía al modelo propuesto por ICRP 67. Tanto la actividad como el número de desintegraciones fue obtenida asumiendo una unica y continua ingesta, para comparar con el método de supervisión propuso por ICRP 78. Considera una unica toma para la mitad del período. El producto de la inhalación es considerado usando el modelo del tracto respiratorio por ICRP 66 y el modelo del yodo de ICRP 67. Este trabajo reproduce las curvas de la fracción activa reportadas por ICRP 78 considerando el yodo como vapor y como aerosoles de 5 µm AMAD.

Palabras Claves: Modelo Bioquinetico, Fracción Activa.

ABSTRACT

Implementation of the model that simulates the radio-iodine biokinetic, proposed by International Commission of Radiological Protection (ICRP), allows the calculation of the activities in organs and excretes of the human body after the intake of radioactive substance. One of the most important organ is thyroid, Because, it has a great uptake of this material, and the urine as main medium of excretion, which are of interest in monitoring programs for individuals who have risk of incorporation when are working with this substance. We have used the eigenvalues and eigenvector method to obtain the activity fractions in organs and excretes, using Matlab 7.0. Numbers of disintegrations were obtain in each compartiment for ^{131}I attending the model proposed by ICRP 67. As much the activity as the number of disintegrations was obtained assuming a single and continuous intake, in order to compare with the monitoring method proposed by ICRP 78. It considers a single intake to half of period. Inhalation intake is considered using the respiratory tract model by ICRP 66 and the iodine model of ICRP 67. This work reproduces the fraction activity curves reported by ICRP 78 considering iodine as vapour and as aerosols of 5 µm AMAD.

Key words: Biokinetic Model, Activity Fraction.

1. Introduction.

^{131}I is a volatile element that can be incorporated by individuals occupationaly exposed as in the case of the routine practices of a Nuclear Medicine service, this can be incorporated as such aerosol or vapour. In Nuclear Medicine the most probable incorporation route is by inhalation.

In this work the respiratory tract model by ICRP66 [1] was implemented, and the sistemic activity model by ICRP 67[2], which allows to have a deep understanding of the processes at compartimental level and they appear number of disintegrations for both cases of incorporation, continuous and single intake are considered, wich are proportional to the committed effective doses.

2. Methodology.

The ICRP 66 [1] considers the deposition model in each compartment of tract depends on the Activity Median Aerodynamic Diameter (AMAD) in case of aerosol or the reactivity and solubility (SR) in case of inhaled vapour, 5 µm AMAD is recommended for the work places and a breathing rate of 1,2 m^3/h for the standard worker. The sistemic activity model of ^{131}I proposed by the ICRP 67[2] considers: Of ^{131}I absorbed in blood 30 % it is absorbed in thyroid and 70 % rest is excreted directly by urinary tract. The biological mean life in blood is 0,25 d. The biological mean life in thyroid is 80 d. In the rest of organs (excluding gastrointestinal tract) the biological mean life is 12 days. The rest of organs absorbs 100 % of retention in thyroid of which 80 % is recirculated in blood and 20 % rest is excreted in organic faeces form.

Biokinetics models were connected both to write the mathematical equations that simulate the metabolic behavior of ^{131}I in the reference man and can to obtain the activity in each organ or excretes like function of the time after the incorporation of 1 Bq of ^{131}I, the equations that simulates the biokinetic model are of the form:

$$\frac{dQo(t)}{dt} = \sum_{i=1}^{n} f_{i\to o} * \lambda_i * Q_i(t) + Do * I(t) - (\lambda_o + \lambda_R)Qo(t) \qquad (1)$$

In where, $dQo(t)/dt$ it is the change of activity in an organ o with time after the incorporation and is function of all the transferences that occur with the other organs. $f_{i\to o}$ is the transference fraction from organ i towards the organ o. λ_i (d^{-1}) Constant of biological decay of the organ i. Q_i (t) Activity of organ i after a time t of the incorporation. λ_o (d^{-1}) Constant of biological decay of the organ o. λ_R (d^{-1}) Constant of radioactive decay of ^{131}I. Do Deposition in the organ o from incorporation. I (t) Function of Incorporation. Solving to the system of equations differentials the activity in each organ Qo (t) for any time (t) is obtained after the incorporation of 1 Bq of ^{131}I.

The number of disintegrations of ^{131}I in each organ in a time t after the incorporation is

$$U(t) = \int_0^T Q_o(t)\,dt \qquad (2)$$

Functions of Incorporation: For the case of single intake is considered the inhalation of 1 Bq of ^{131}I at t = 0, this function is represented as an unitary impulse. For the case of continuous intake is considered that the incorporation of 1 Bq of ^{131}I happens during 30 days, with which obtains an incorporation of 0,033 Bq per day.

The equations that regulate the biokinetic model of ^{131}I are of the form (1). Where the fractions, the models of deposit and the biological constants are reported in the ICRP publications 66[1] and 67[2], the time of mean physical life is $T_{1/2}$=8,04 d. were constructed the equations of the compartments. A system of equations differentials was obtained with which is constructed matrix of order nxn, the incorporation function is a vector where each entrance is given by the fraction of deposit in each compartment. Making use of eigenvalues and eigenvector method by means of Matlab 7,0 the system for the single intake of 1 Bq was solved and the activities for each compartment based on any time t after the incorporation are obtained, for the case of the continuous incorporation It's used the Laplace transformed method. For all the cases graphical the activity retained in the thyroid likes function of the day after the incorporation of 1 Bq of ^{131}I. the function of excretion in daily urine was graficated considering the correction by radioactive decay of excreted urine in the previous day, $QoD(t)=Qo(t)–Qo(t-1)*e^{-(\lambda R)}$ .The number of disintegrations for each compartment in 50 years is calculated of the form (2).

3. Results.

Funtions of thyroid retention and daily urine excretion was graficated for the single intake case.

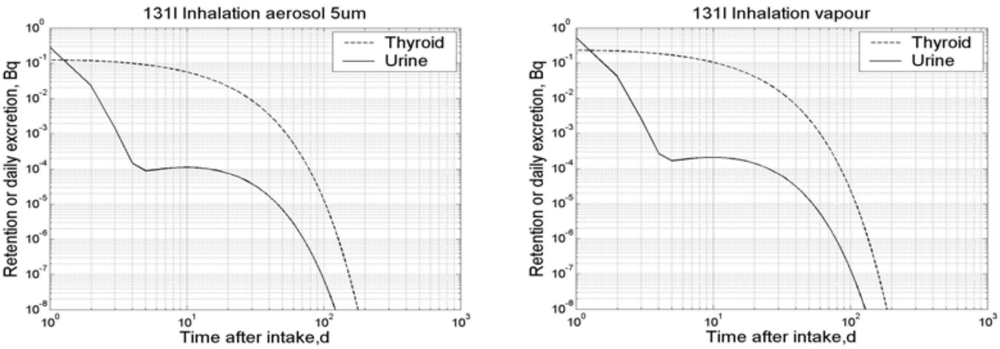

Figure No 1. Single intake. Retention or daily excretion (Bq). Inhalation of ^{131}I. Left aerosol, right vapour

For the continuos intake case.

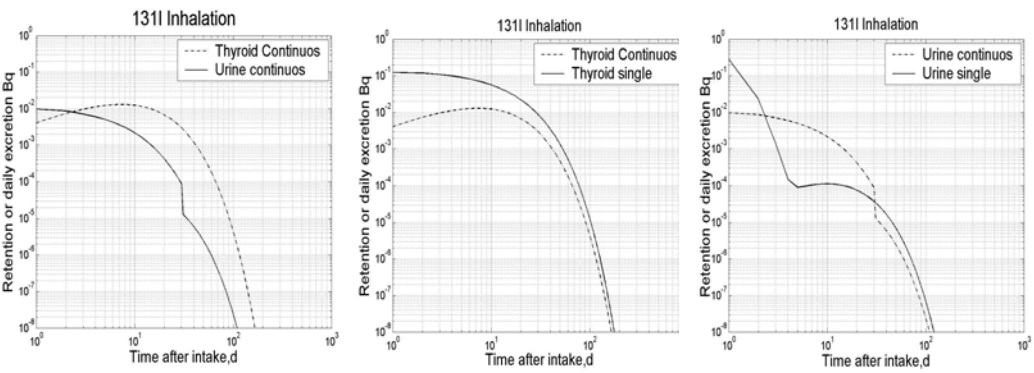

Figure No 2. Continuos intake. Retention or daily excretion (Bq). Inhalation of ^{131}I. Left Thyroid and urine, middle thyroid continuos and single, right Urine continuos and single

Number of disintegrations that ^{131}I has in each compartment of the model of ICRP 67[2] of the form (2) and was obtained the results for the thyroid and whole body which are reported in Table 1.

Table No 1. Comparation betwen desintegrations single and continuos

Disintegrations	Thyiroi	Whole Body
Single Intake	1.49	1.79
Continuos Intake	0.27	0.29

In figure 1. the fractions of activity in Thyroid were obtained and daily excreciòn in urine, which agrees with the reported ones by ICRP 78[3]. With which one confirms the biokinetic model and method of solution implemented. It sees how for measurements of bioassays is more important medition on thyroid that on urine. It is important to observe from the behavior of figure 2, how the activity fraction in thyroid in the continuous incorporation is minor in case of single intake, which is ratified in the calculatus of the number of disintegrations by the two forms of incorporation; and therefore the number of disintegrations affect the estimations of the committed equivalent doses H_T (50) in an organ and of the committed effective dose E (50).

4. Conclusions.

The committed effective dose E (50) due to a single intake is greater than the continous intake; ICRP 78 recommends to calculate the dose as if the incorporation went to half of monitoring period, which in terms of radiological protection is a demanding criterion with respect to the doses limits. With relation to solution method it can see that this is the same for the single and continuos intakes, and the diference appear like an aditional fraction that simulates the intake frecuency [5].

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