HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2018 Vol.7, No.2 110–116

REM
Radiat Environ Med

Regular Article

Taking into Account of the Correlation between Absorbed Fractions in Uncertainty Assessment in Biokinetic and Dosimetric Models of α-, β -, αγ-, and βγ-emitters: Case of ^{238}U and ^{210}Pb

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Received 19 January 2018; revised 7 April 2018; accepted 8 May 2018

The aim of this study is to assess the contribution of the correlation between absorbed fractions of organs/tissues, to the overall relative uncertainty of the ingestion dose coefficients, otherwise of biokinetic and dosimetric models of α-, β-, αγ-, and βγ-emitters. ^{238}U an αγ-emitter, and ^{210}Pb an βγ-emitter were considered for calculations. The overall relative uncertainty of the ingestion dose coefficient ranging from 124% to 175% for ^{238}U, and 206% to 287% for ^{210}Pb was assessed, by ranging the relative uncertainty on the numbers of transformations, the absorbed fractions, the radiation and tissue weighting factors, and the wall parameter from 5% to their nominal values in the literature and by considering the weighting correlated coefficient between absorbed fractions at 5%, to take into account of the importance of the target or source organs/tissues according to their specific absorbed fractions. Finally the correlation between absorbed fractions of organs/tissues mostly affects the weighted relative uncertainty of absorbed fractions at around 88%. But because of the low contribution of this parameter in the assessment of overall relative uncertainty, this correlation between absorbed fractions has a very low impact in the final result.

Key words: Ingestion dose coefficient, absorbed fraction, uncertainty, correlation, dosimetric model, biokinetic model

1. Introduction

Assessment of the fraction of the uptake transferred to particular organs or tissues of the body, the subsequent behavior of the radioactive material in those organs and tissues and in the transfer compartment, assessment of the absorbed doses in organs and tissues of the body per decay of the radionuclides in each source organ or transfer compartment are the components of dose calculations which involves the use of biokinetic and dosimetric models. Biokinetic models calculate the time-dependence of activity of the radionuclides in each source organ or transfer compartment per unit activity absorbed into body fluids, and dosimetric models are based on radionuclide decay data and calculations of radiation transport in model representations of human anatomy and elemental compositions of organs and tissues[1, 2]. These models have been used by ICRP[3] to calculate the ingestion dose coefficients and are not subject of uncertainty when they are used in a Reference Person[4]. Uncertainty needs to be taken into account

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when these standardized models are used in others areas such as toxicology, pharmacology, medicine and dose reconstruction for epidemiological studies[5]. Because in these particular areas biokinetic models do not take into account of disease state, functional organ impairment, the influence of other medications, or other influences that can substantially alter anatomical models, and the considerable variability seen across the group of subjects. It is important to distinguish between uncertainty and variability or more correctly to consider variability as a component of uncertainty in certain cases[6].

Although uncertainty and variability are distinct concepts, the variability in biokinetic characteristics within a population is often an important factor contributing to the uncertainty in a central estimation of a biokinetic quantity. This confidence that can be placed in prediction of a biokinetic model for an element or compound depends not only on uncertainties associated with parameter values of model, but also on uncertainties associated with the model structure. Such uncertainties may arise because the structure provides an oversimplified representation of the known processes, because unknown processes have been omitted from the model or because part or all of the model formulation is based on mathematical convenience rather than consideration processes. In the present paper, analytical formula of relative uncertainty of ingestion dose coefficient which was brought out in the previous paper[1] was updated by taking into account of the correlation between Absorbed Fractions in organs/tissues and applied to specific cases of ^{238}U an αγ-emitter and ^{210}Pb an βγ-emitter.

2. Materials and Methods

2.1. Biokinetic models of ^{238}U and ^{210}Pb

To define the movement of radionuclides within alimentary and respiratory tracts, and to calculate the number of transformations for individual elements and their radioisotopes occurring within specific organs/tissues, or body regions during a given period of time which is standardized to 50 years for adults (who are assumed to be at a reference age of 20 years at time of exposure) or a variable time to 70 years of age for those exposed as infants, children or adolescents[5], biokinetic models of these systems are used. The numbers of transformations of radionuclide whose formula was brought out in our first paper were determined by using MAPLE 13 software and to calculate the retention function MATHEMATICA 5 has been used[1]. The accuracy has been taken by default for the above softwares. By default, MAPLE calculates the result to 10 digits of accuracy, but one can specify any number of digits wanted. For MATHEMATICA it calculates the result to 16 digits of accuracy, but it also allows to specify the number of digits wanted in numerical computation.

In the present study the correlation between absorbed fractions of organs/tissues is taken into account, compared to the previous work reported recently by the same authors[1]. The biokinetic models of lead and uranium have been used[7]. Lead that follows the movement of calcium in the body to a large extent and that physiologic regulators of calcium metabolism usually affect the behavior of lead in a qualitatively similar fashion, particularly their behavior in bone which is similar with the behavior of other alkaline earth elements among different bones and between trabecular and cortical bone structure, that have been proved with data on humans and laboratory animals which indicated that long-term skeletal distribution and retention are similar for lead and the alkaline earth elements[8]. The biokinetic model of uranium describes in details the movement of uranium in bone which is the main site of deposition and retention, and considers also retention in kidneys, liver and other soft tissues as well as routes of excretion. The model takes also into account of initial uptake onto bone surfaces, transfer from surface to bone volume and recycling from bone and other tissues to plasma. A f_1 value which is a fractional uptake from gastrointestinal tract to blood has been taken as 0.02 for uranium and 0.2 for lead, appearing to be more realistic values[9].

2.2. Dosimetric models of α-, β-, αγ-, and βγ-emitters

Dosimetric models are used to calculate the deposition of energy in all important organs/tissues (targets) for transformations occurring in each source region, taking account of the energies and yields of all emissions[10]. Formulae of this model were brought out in our previous paper[1].

2.3. Uncertainty of ingestion dose coefficients of α-, β-, αγ-, and βγ-emitters

The ingestion dose coefficient of αγ- and βγ-emitters defined as the effective dose corresponding to 1 Bq of radionuclide intake[1] is given as follows:

$$e_{ing} = \frac{1}{4} k \sum_{R,i} w_{R,i} p_i E_i \sum_{T,S} w_T U_S \left[\nu \left(\frac{1}{M_T^C} + \frac{1}{M_{T'}^C} \right) + 2 \left(\frac{AF(T \leftarrow S)}{M_T} + \frac{AF(T' \leftarrow S)}{M_{T'}} \right) \right] \quad (1)$$

Where $k = 1.6 \times 10^{-10}$ is the conversion factor, $w_{R,i}$ is the radiation weighting factor for α-particles is equal to 20 and 1 for β-particles and γ-radiation, p_i is the yield of radiations of type i per nuclear transformation, E_i is the average or unique i energy of radiation type i, w_T are the tissue weighting factors, v is the wall parameter to account for the reduced α-dose to radiosensitive cells in

the wall it is taken to be unity for β-particles and 0.01 for α-particles, U_S is the numbers of transformation of radionuclide, M_T^C is the mass of the walled organ, $AF(T \leftarrow S)$ is the fraction of energy emitted in source region S that is i absorbed within target region T and M_T is the mass of target region T. It is important to underline that the term $\nu\left(\frac{1}{M_T^C}+\frac{1}{M_{T'}^C}\right)$ is used only for walled organs.

Updated values of tissue weighting factors[5] and specific absorbed fractions calculated by Cristy and Eckerman[11] have been used. Equation (1) can be generalized to pure α- and β-emitters. In this case the Absorbed Fractions AF=1, due to the total absorption of α- and β-particles within the source organ. Exceptions are within skeletal structures and within regions of the respiratory tract described in ICRP Publication 66[12].

The relative uncertainty of ingestion dose coefficients has been computed using the methodology described in the Guide of the Uncertainty Measurements (GUM)[13].

The combined standard uncertainty $u_c(y)$ is the positive square root of the combined variance $u_C^2(y)$.

$$u_C^2(y)=\sum_{i=1}^{N}\left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i) \tag{2}$$

Where $y=e_{ing}=f(w_R, w_T, p_R, E_R, v, U_S, M_T^C, M_{T'}^C, M_T, M_T, AF_T)$. However, this equation is valid only if the input quantities x_i are independent or uncorrelated. If some of the quantities x_i are significantly correlated, the correlations must be taken into account.

When the input quantities are correlated, the appropriate expression for the combined variance associated with the result of a measurement is:

$$u_C^2(y)=\sum_{i=1}^{N}\left(\frac{\partial f}{\partial x_i}\right)^2 u^2(x_i)+2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\left(\frac{\partial f}{\partial x_i}\right)\left(\frac{\partial f}{\partial x_j}\right)u(x_i,x_j) \tag{3}$$

The second term in the right hand of equation 3 is called "correlation term".

The correlation term in our study is the correlation between absorbed fractions (AFs) of each source and corresponding targets. AFs are defined as the proportion of energy deposited in the target organ released in source organs, but the SAFs which is more informative and comprehensive than AFs is defined as the ratio of AF and target mass. The study of Cristy and Eckerman[11] and the following equation:

$$\sum_T M_T\left(\frac{AF(T\leftarrow S)}{M_T}\right)=1 \tag{4}$$

show the strongly negative correlation between the AFs of each source and the corresponding target, this proves that the value of correlation coefficient $x_{(AF(S\leftarrow S),\,AF(T\leftarrow S))}=-1$. And looking for importance of target classified as 'highest targets', 'neighbouring targets', 'nearby targets' and 'irrelevant targets' according to their AFs values[14], this correlated coefficient is weighted by 0.05 which is the arithmetic average of the ratio of AFs of non-self-absorption and the AFs of self-absorption.

In the previous study the uncertainty of ingestion dose coefficient by neglecting the correlation term is given as follows:

$$\left(\frac{u_{e_{ing}}}{e_{ing}}\right)^2=\sum_{i=1}^{2}f_{w_{r_i}}^2\left(\frac{u(w_{r_i})}{w_{r_i}}\right)^2+\sum_{j=1}^{5}f_{E_{r_j}}^2\left(\frac{u(E_{r_j})}{E_{r_j}}\right)^2+\sum_{j=1}^{5}f_{p_{r_j}}^2\left(\frac{u(p_{r_j})}{p_{r_j}}\right)^2+$$
$$\sum_{k=1}^{20}f_{w_{T_k}}^2\left(\frac{u(w_{T_k})}{w_{T_k}}\right)^2+\sum_{k=1}^{20}f_{U_{S_k}}^2\left(\frac{u(U_{S_k})}{U_{S_k}}\right)^2+f_{\nu}^2\left(\frac{u(\nu)}{\nu}\right)^2+\sum_{l=1}^{7}f_{M_{T_l}^c}^2\left(\frac{u(M_{T_l}^c)}{M_{T_l}^c}\right)^2$$
$$+\sum_{l=1}^{7}f_{M_{T_l}^c}^2\left(\frac{u(M_{T_l}^c)}{M_{T_l}^c}\right)^2+\sum_{k=1}^{20}f_{M_{T_k}}^2\left(\frac{u(M_{T_k})}{M_{T_k}}\right)^2+\sum_{k=1}^{20}f_{M_{T_k'}}^2\left(\frac{u(M_{T_k'})}{M_{T_k'}}\right)^2+$$
$$\sum_{k=1}^{20}f_{AF_k}^2\left(\frac{u(AF_k)}{AF_k}\right)^2+\sum_{k=1}^{20}f_{AF_k'}^2\left(\frac{u(AF_k')}{AF_k'}\right)^2 \tag{5}$$

By considering the correlation term of AFs of each source organ according to their corresponding target, and knowing that precision to determine the absorbed fraction is independent of the gender, the overall relative uncertainty of ingestion dose coefficient is given by the following equation:

$$\left(\frac{u_{e_{ing}}}{e_{ing}}\right)^2=\sum_{i=1}^{2}f_{w_{r_i}}^2\left(\frac{u(w_{r_i})}{w_{r_i}}\right)^2+\sum_{j=1}^{5}f_{E_{r_j}}^2\left(\frac{u(E_{r_j})}{E_{r_j}}\right)^2+\sum_{j=1}^{5}f_{p_{r_j}}^2\left(\frac{u(p_{r_j})}{p_{r_j}}\right)^2+\sum_{k=1}^{20}f_{w_{T_k}}^2\left(\frac{u(w_{T_k})}{w_{T_k}}\right)^2$$
$$+\sum_{k=1}^{20}f_{U_{S_k}}^2\left(\frac{u(U_{S_k})}{U_{S_k}}\right)^2+f_{\nu}^2\left(\frac{u(\nu)}{\nu}\right)^2+\sum_{l=1}^{7}f_{M_{T_l}^c}^2\left(\frac{u(M_{T_l}^c)}{M_{T_l}^c}\right)^2+\sum_{l=1}^{7}f_{M_{T_l}^c}^2\left(\frac{u(M_{T_l}^c)}{M_{T_l}^c}\right)^2$$
$$+\sum_{k=1}^{20}f_{M_{T_k}}^2\left(\frac{u(M_{T_k})}{M_{T_k}}\right)^2+\sum_{k=1}^{20}f_{M_{T_k'}}^2\left(\frac{u(M_{T_k'})}{M_{T_k'}}\right)^2+\sum_{k=1}^{20}f_{AF_k}^2\left(\frac{u(AF_k)}{AF_k}\right)^2+\sum_{k=1}^{20}f_{AF_k'}^2\left(\frac{u(AF_k')}{AF_k'}\right)^2$$
$$-0.1\sum_{k=1}^{19}\sum_{k'=k+1}^{20}\left[f_{AF_k}f_{AF_{k'}}\left(\frac{u(AF_k)}{AF_k}\cdot\frac{u(AF_{k'})}{AF_{k'}}\right)+f_{AF_k'}f_{AF_{k'}'}\left(\frac{u(AF_k')}{AF_k'}\cdot\frac{u(AF_{k'}')}{AF_{k'}'}\right)\right] \tag{6}$$

Where k and k' refer to number of organs/tissues whose tissue weighting factor is known. A subroutine FORTRAN 90 has been used to determine the relative uncertainty of the ingestion dose coefficient of ^{210}Pb, an $\beta\gamma$-emitter and ^{238}U, an $\alpha\gamma$-emitter.

3. Results and discussion

3.1. Results

The present study has been performed using 12 parameters whose contributions to the overall relative uncertainty of ingestion dose coefficient are presented in Tables 1 and 2. The variations of the overall relative uncertainty on the ingestion dose coefficient versus the variation of weighted relative uncertainty of the Absorbed Fractions, the number of transformations, the

Table 1. Contribution of each variable of the ingestion dose coefficient to the overall relative uncertainty of ^{210}Lead

Variable	Weighted relative uncertainty without taking into account of correlation between AFs $f_{xi}(u_{xi}/x_i)$ (%)	Weighted relative uncertainty taking into account of the correlation between AFs $f_{xi}(u_{xi}/x_i)$ (%)
Radiation weighting factor, w_R	0.17	0.176
Emission probability, p_i	0.00101	0.00103
Energy, E_i	0.00114	0.00117
Tissue weighting factor, w_T	1.14	1.17
Number of transformations, U_S	1.14	1.17
Wall parameter, v	0.057	0.058
Mass of contents (man), M_T^C	12.68	12.96
Mass of contents (woman), $M_{T'}^C$	11.88	12.14
Mass of organ/tissue (man), M_T	34.18	34.94
Mass of organ/tissue (woman), $M_{T'}$	36.42	37.23
Absorbed Fraction (man), AF_T	1.14	0.06
Absorbed Fraction (woman), $AF_{T'}$	1.14	0.056

Table 2. Contribution of each variable of the ingestion dose coefficient to the overall relative uncertainty of ^{238}Uranium

Variable	Weighted relative uncertainty without taking into account of correlation between AFs $f_{xi}(u_{xi}/x_i)$ (%)	Weighted relative uncertainty taking into account of the correlation between AFs $f_{xi}(u_{xi}/x_i)$ (%)
Radiation weighting factor, w_R	0.37	0.378
Emission probability, p_i	0.038	0.0076
Energy, E_i	0.0017	0.00173
Tissue weighting factor, w_T	1.21	1.23
Number of transformations, U_S	1.21	1.23
Wall parameter, v	0.057	0.057
Mass of contents (man), M_T^C	12.4	12.45
Mass of contents (woman), $M_{T'}^C$	11.6	11.89
Mass of organ/tissue (man), M_T	34	34.7
Mass of organ/tissue (woman), $M_{T'}$	36.6	37.43
Absorbed Fraction (man), AF_T	1.17	0.14
Absorbed Fraction (woman), $AF_{T'}$	1.16	0.13

radiation and tissue weighting factors, and of the wall parameter[1)] are showing in Figures 1a; 1b; 1c; and 1d. The variation of overall uncertainty related to ^{210}Pb (Fig. 1a.) and ^{238}U(Fig. 1c.) by taking into account the correlation between AFs, and without correlation term (Fig. 1b; 1d) shows similar linear variation of the curves of weighted relative uncertainty of wall parameter v and radiation weighting factors w_R. These two parameters are not really affected by the correlation term between AFs as shown in Tables 1 and 2. In Figures 1a; 1b; 1c; and 1d, the curves of weighting relative uncertainty of U_S, w_T, and AFs are confused without correlation term (Fig. 1b and Fig. 1d), and these curves are dislocated, when correlation term is considered (Fig. 1a and Fig. 1c).

The correlation is taken into account, and in this case the curves of AFs are above those of U_S and w_T, that show that the correlation affects considerably AFs than U_S and w_T. That is also shown in tables 1 and 2 where there is an important decrease of 88% of the contribution of AFs.

Taking into account the correlation term between AFs, and by ranging relative uncertainties of v, w_R, U_S , w_T, and AFs at 5%, the overall relative uncertainty of ingestion dose coefficient of 206% for ^{210}Pb and 124% for ^{238}U have been obtained and without considering correlation term, 208% has been obtained for ^{210}Pb and 126% for ^{238}U. The decrease of the overall uncertainty is roughly of 2% in the two cases. The same order of decrease is observed when ranging the relative uncertainty of U_S, w_T and w_R at 20%, AFs at 5% and v at 50%. Based on the optimal values of relative uncertainties commonly reported in the literature[5, 15-18)] for AFs at 5%, U_S , w_T, and w_R at 30%, and for v at 50%, the overall relative uncertainty of ingestion dose coefficient by taking into account the correlation term was found to be 287% for ^{210}Pb, and 175% for ^{238}U. And without considering correlation term the overall relative uncertainty was found to be 289% for ^{210}Pb and 176% for ^{238}U.

3.2. Discussion

The contribution of weighted relative uncertainty in

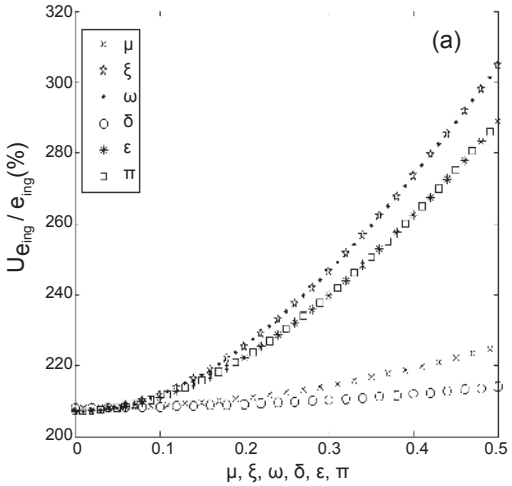

Fig. 1.a. Variation of relative uncertainty of ingestion dose coefficient of lead-210 depending on the weighted relative uncertainty on the number of transformation, on the radiation and tissue weighting factors, on the absorbed fractions, and on the wall parameter, taking into account of the correlation between absorbed fractions.

$$\mu = f_{w_{r_i}} \frac{u_{w_{r_i}}}{w_{r_i}};\ \xi = f_{w_{T_i}} \frac{u_{w_{T_i}}}{w_{T_i}};\ \omega = f_{U_{S_i}} \frac{u_{U_{S_i}}}{U_{S_i}};\ \delta = f_v \frac{u_v}{v};\ \varepsilon = f_{AF_i} \frac{u_{AF_i}}{AF_i};\ \pi = f_{AF_i'} \frac{u_{AF_i'}}{AF_i'}$$

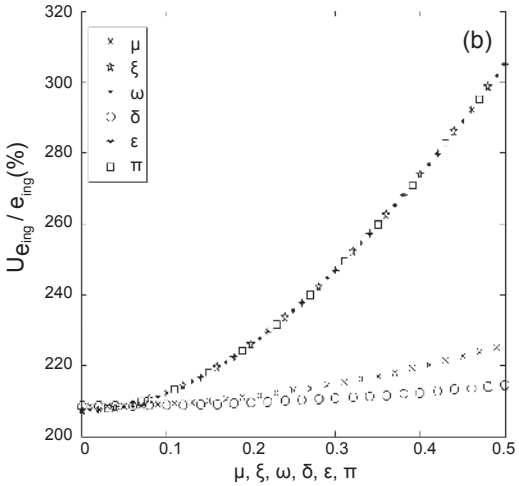

Fig. 1.b. Variation of relative uncertainty of ingestion dose coefficient of lead-210 depending on the weighted relative uncertainty on the number of transformation, on the radiation and tissue weighting factors, on the absorbed fractions, and on the wall parameter, without consideration of correlation between absorbed fractions.

$$\mu = f_{w_{r_i}} \frac{u_{w_{r_i}}}{w_{r_i}};\ \xi = f_{w_{T_i}} \frac{u_{w_{T_i}}}{w_{T_i}};\ \omega = f_{U_{S_i}} \frac{u_{U_{S_i}}}{U_{S_i}};\ \delta = f_v \frac{u_v}{v};\ \varepsilon = f_{AF_i} \frac{u_{AF_i}}{AF_i};\ \pi = f_{AF_i'} \frac{u_{AF_i'}}{AF_i'}$$

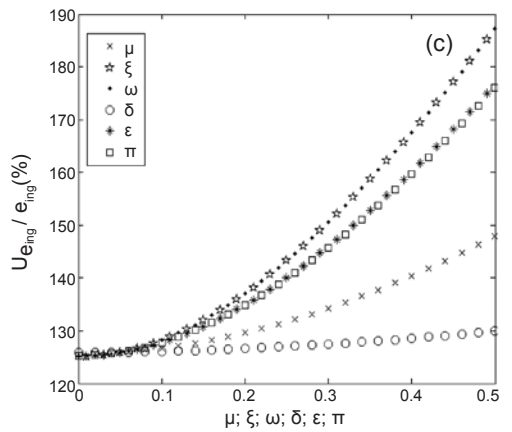

Fig. 1.c. Variation of relative uncertainty of ingestion dose coefficient of uranium-238 depending on the weighted relative uncertainty on the number of transformation, on the radiation and tissue weighting factors, on the absorbed fractions, and on the wall parameter, taking into account of the correlation between absorbed fractions.

$$\mu = f_{w_{r_i}} \frac{u_{w_{r_i}}}{w_{r_i}};\ \xi = f_{w_{T_i}} \frac{u_{w_{T_i}}}{w_{T_i}};\ \omega = f_{U_{S_i}} \frac{u_{U_{S_i}}}{U_{S_i}};\ \delta = f_v \frac{u_v}{v};\ \varepsilon = f_{AF_i} \frac{u_{AF_i}}{AF_i};\ \pi = f_{AF_i'} \frac{u_{AF_i'}}{AF_i'}$$

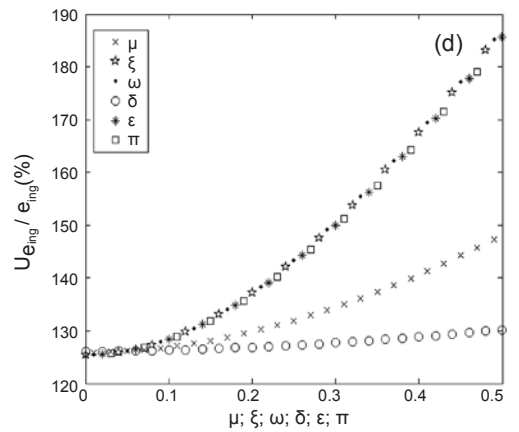

Fig. 1.d. Variation of relative uncertainty of ingestion dose coefficient of uranium-238 depending on the weighted relative uncertainty on the number of transformation, on the radiation and tissue weighting factors, on the absorbed fractions, and on the wall parameter, without consideration of correlation between absorbed fractions.

$$\mu = f_{w_{r_i}} \frac{u_{w_{r_i}}}{w_{r_i}};\ \xi = f_{w_{T_i}} \frac{u_{w_{T_i}}}{w_{T_i}};\ \omega = f_{U_{S_i}} \frac{u_{U_{S_i}}}{U_{S_i}};\ \delta = f_v \frac{u_v}{v};\ \varepsilon = f_{AF_i} \frac{u_{AF_i}}{AF_i};\ \pi = f_{AF_i'} \frac{u_{AF_i'}}{AF_i'}$$

decay data terms E_R and P_R, and in wall parameter v is low and mostly negligible as shown in Tables 1 and 2, in comparison with other weighted relative uncertainties in other intervening parameters. These decay data terms and wall parameter are not considerably affected by the correlation term.

The radiation factors used to calculate equivalent dose are simplified values that do not reflect the complexities of the scientific data on which they are based. Equivalent dose was not intended and should not be used, as best estimate of dose relating to risk to specific individuals or population groups[19]. It was duly emphasized and was also expressed in the designation of a nominal risk coefficient that there are uncertainties in the extrapolation of observations at high doses to the small and often minute doses that are at issue in the radiation protection of workers or the public. These uncertainties go beyond the imprecision of numbers that is due to

imperfect observations and statistical errors; there are, instead, primarily determined by the lack of accuracy that stems from plausible, but unproven, assumptions and extrapolations that are required in any workable and sufficiently conservative system of risk assessment[18]. Contribution of weighted relative uncertainty of radiation weighting factor w_r is relatively low but not negligible in overall relative uncertainty of ingestion dose coefficient, and this parameter is not really affected by the correlation term as shown in Tables 1 and 2.

Dose from ingestion example of α-emitters to all regions of the alimentary tract will be solely due to its absorption into blood, and subsequent irradiation from systemic activity to soft tissue when there is no retention of radionuclides in the alimentary tract wall. Knowing that available types of data or of information used to construct the biokinetic models for elements are different including human data involving quantitative measurement of elements, observation of behavior of chemically similar elements, observation of behavior of the elements in non-human species; and observations of the behavior of one or more chemically similar elements in non-human species[20]. In addition, knowing that the effect on effective dose is small for radionuclides with large f_1 values or long-lived radionuclides with long-term retention in the body, contribution of weighted relative uncertainty of number of transformation U_S and weighting tissue factor w_T are the same as shown in Tables 1 and 2. These two parameters are no more affected by correlation term but have a low contribution in overall relative uncertainty of ingestion dose coefficient.

To achieve wide applicability, the protection quantities are defined using mathematical models with broad averaging of body-related parameter values. Specially, anatomical and physiological parameters of reference individuals, collectively referred to as Reference Man, are given in ICRP publication 89[21] which serve as the basis of reference biokinetic models and as the basis of computational phantoms used in the calculations of dose coefficients[10]. Otherwise the mass of certain organs varies more than others with changes in body sizes; according to that, the contribution of weighted relative uncertainty of mass to overall relative uncertainty of ingestion dose coefficient of lead-210 and uranium-238 by taking into account the correlation term is 97%, and without taking it into account is 95% as shown in Tables 1 and 2. This slight variation between these two values shows the low impact of the correlation term in the determination of the overall relative uncertainty of ingestion dose coefficient. However, the contribution is very large because of little information about the mass of organs available. For example the mass of bone surface and even the definition of bone surface is debated among investigators. One should also note that the autopsy sample set from Grandmaison *et al.*[22] was relatively small (684 cases). Thus some statistical uncertainty is clearly associated with data[23].

The absorbed fraction for gamma radiation are affected by uncertainty due to the lack of knowledge about the precise position and shape of each target organ, the relative size of the whole body and of each target organ, and by statistical uncertainties introduced by the methods used to solve the radiation transport problem. On the other hand the SAFs used in most internal dose calculations are based on standardized individuals, that is, reference man, reference woman, reference pediatric individuals and so on. The phantoms or anthropomorphic models, that have been derived to represent these standard individuals, when used in these calculations, provide doses to the supposedly median individual in a reference group. And when this dose estimation is transposed to an individual who does not belong to that reference group, this SAF becomes a significant source of uncertainty in the numeric values of the dose estimated[15]. Contribution of weighted relative uncertainty of absorbed fractions to overall relative uncertainty of ingestion dose coefficient by taking into account of the correlation term shown in Tables 1 and 2 is around 88% less than when it is without the correlation term for lead-210 and uranium-238. This higher variation shows considerable impact of the correlation term on AFs. However, given the current advancements in the Monte Carlo methods for radiation transport together with a developed geometrical model of humans, it is expected that the statistical uncertainties are much smaller than the uncertainties related to the size and position of different organs[24].

4. Conclusion

A systematic study was performed to take into account the correlation between absorbed fractions in uncertainty assessment in biokinetic and dosimetric models of α-, β-, αγ-, and βγ-emitters. The overall relative uncertainty of ingestion dose coefficient ranging from 206% to 287% for lead-210 a βγ-emitter, and from 124% to 175% for uranium-238 an αγ-emitter was brought out by considering 12 parameters intervening in the expression of dose coefficient. The correlation term not affect independent parameter such as decay data terms but mostly affects parameters depending each other such as weighted relative uncertainty of absorbed fractions around 88%, but because of the low contribution of this weighting relative uncertainty of absorbed fractions in the assessment of overall relative uncertainty, this correlation term has a very low impact in the final result. This formula can be extended to the overall uncertainty assessment of inhalation dose coefficients.

Conflict of Interest Disclosure

The authors declare that they have no conflict of interest.

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