INFLUENCE OF THE ELECTION OF THE REMAINDER IN THE ASSESSMENT OF THE EFFECTIVE DOSE EQUIVALENT

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INTRODUCTION

The effective dose equivalent, H_E, was defined in ICRP Pub. 26 (1) for stochastic effects on the basis of the principle that risks arising from whole-body uniform irradiations and from non-uniform irradiations are equal. The H_E is the weighted mean whole-body dose equivalent defined by means of equation /1/. In addition to those organs explicitly quoted in Table 1, this equation involves a non-specific set of organs called "remainder". This has been defined as the set of 5 organs with the highest dose equivalents, excluding those explicitly indicated.

This paper raises the fact that the remainder definition is not precise and that this leads to great indeterminations in the value of the H_E for the case of non-homogeneous exposures.

ANTECEDENTS OF THE REMAINDER PROBLEM

Several authors have made different interpretations of the definition of the remainder. Bengtsson, L. (2) considered the mean trunk dose equivalent as the remainder dose equivalent. Kramer, R. (3) used a fixed remainder model composed by stomach, liver, upper large instestine (ULI), small intestine (SI) and pancreas. Whøni,T. (4) considered the GI dose equivalent as the remainder dose equivalent. ICRP Pub. 30 (5) used the list of organs shown in Table 2 as a reference set. Maruyama, T. (6) considered brain, stomach, liver, rectum and ULI. Finally, in another work (7), the author used a different set composed by SI, LI, stomach, kidneys, pancreas, spleen, liver, adrenals, brain, bladder and heart, as a reference set.

These diverse interpretations arise because the ICRP has not explicitly defined the set of reference organs from which the remainder is to be selected. ICRP Pub. 26, paragraph 66, reads that certain irradiated tissues may be ignored for radiation protection purposes, but it does not specify which are those tissues.

Since the remainder is the "organ" with the maximum weight factor, as may be seen in Table 1, its influence needs to be studied when the H_E must be assessed. Kramer, R. (8) demonstrated that, for whole-body irradiations in photon parallel fields, the differences in the H_E calculated on the basis of fixed or variable remainder models are below 17% for energies higher than 50 KeV. In cases of non-homogeneous exposures, the differences may be far higher, as shown in this paper through two practical cases described below.

ASSESSMENT OF THE EFFECTIVE DOSE EQUIVALENT

The influence of the remainder selection for occupationally exposed workers was analyzed in two practical cases. The first case refers to a routine gynecological practice with Ra-226, for which an assessment was made of the H_E absorbed by the ginecologist during a given practice. The physician performs the implantation seated behind a lead shield and is mainly exposed in upper limbs, head and upper thorax. Details on the development of this routine practice have been published by Eckerl, H. (9) and Spano, F.(10)

The second case refers to the H_E resulting from an event occurred during maintenance work performed on an x-ray equipment unit. A technician stood for 20 minutes facing an x-ray tube at 170 kVp and was exposed in head and upper thorax. Although the H_E was not defined for its application in this type of events, its value was calculated in order to show the influence of the remainder selection in cases of strongly non-homogeneous irradiation.

The H_E was defined in ICRP Pub.26(1) by means of the equation:

$$H_E = \sum_T W_T H_T \qquad /1/$$

where:

W_T is the weighting factor representing the proportion of the stochastic risk resulting from tissue T to the total risk, when the whole body is irradiated uniformly. The male W_T factors used in this work are shown in Table 1.

H_T is mean dose equivalent in tissue T.

Table 1

Male risk coefficients

Tissue	Absolute (10^{-6} rem^{-1})	Relative
Testes	40	0.283
Red bone marrow	20	0.141
Lungs	20	0.141
Thyroid	5	0.035
Bone surface	5	0.035
Skin	1	0.007
Remainder	50	0.354

The mean organ dose equivalent absorbed by the physician was obtained through the development of a mathematical model based on the application of the Monte Carlo method to photon transport in a MIRD V phantom developed by Spano, F.(10) In the case of the x-ray incident, the distribution of the dose equivalent was obtained by using a Rando phantom and 3 x 3 x 1 mm^3 LiF and CaF:Dy thermoluminiscent dosimeters.

The H_E was assessed on the basis of four different remainder models described in Table 2. The first one is a fixed remainder defined by Kramer, R.(3) The second one considers the target tissues given in Table 4.1 of ICRP Pub. 30 (5) (except for muscle and

the organs included in Table 1) as a reference organ set. This paper introduces, as a third reference organ set, a selection of the original organ list in ICRP Pub. 23. The fourth model considers the head mean dose equivalent as the remainder dose equivalent.

Table 2

Remainder Models

Kramer:
Stomach, ULI, SI, liver and pancreas.
ICRP30:
ST wall, SI wall, ULI wall, LLI wall, kidneys, liver, pancreas, spleen, thymus, uterus, adrenals and bladder wall.
Organs selected from the ICRP 23 list:
Adrenals, brain, esophagous, eyes, gall bladder, stomach, SI, ULI, LLI, kidneys, larynx, liver, tonsils, pancreas, parathyroid, pineal gland, pituitary gland, prostate gland, salivary glands, spleen, thymus, trachea, ureters, urethra and urinary bladder.
Mean Head Dose Equivalent: as the remainder dose equivalent.

Tables 3 and 4 show the H_Es, as functions of the four selected remainder models, for the physician performing the practice with Ra-226 and for the technician who suffered the x-ray exposure respectively.

Table 3

Effective Dose Equivalent: Physician in Radiumtherapy

Remainder Model	Effective Dose Equivalent (mrem)
Kramer	2.1
ICRP 30	2.7
Organs selected from ICRP 23 list	4.3
Mean head dose equivalent	3.2

Table 4

Effective Dose Equivalent: Technician in X-ray Incident

Remainder Model	Effective Dose Equivalent (mrem)
Kramer	6.466
ICRP 30	8.667
Organs selected from ICRP 23 list	56.995
Mean head dose equivalent	23.270

CONCLUSIONS

The differences found in the H_E absorbed by the physician during the radiumtherapy, as a function of the adopted remainder model, reach a factor of 2.1. This factor is obtained by comparing the values resulting from the application of a fixed remainder defined by Kramer, R. (3) and of a variable remainder based on the organ list in ICRP Pub. 23 (11), as shown in Table 2. The difference obtained from the same comparison performed on the technician who suffered the x-ray incident reached a factor of 8.8 in the H_E values.

Similar variations may be found for the H_E resulting from non-homogeneous irradiations, specially when involving head and upper thorax exposures.

The results obtained indicate that the present definition of the remainder is not precise and that it leads to great indeterminations in the value of the H_E. Therefore, the set of organs from which the remainder is to be selected should be explicitly defined.

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