EXPOSURE MODEL FOR A GYNECOLOGIC RADIUMTHERAPY.

ASSESSMENT OF EFFECTIVE DOSE EQUIVALENT

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INTRODUCTION

An exposure mathematical model has been developed in order to assess the mean organ equivalent dose and the effective dose equivalent, H_E, absorbed by occupationally exposed workers during a gynecological practice with Ra-226.

The H_E -defined in ICRP Pub. 26 (1)- that is absorbed by a worker during a practice involving ionizing radiations is generally hard to estimate. Usually, the knowledge of the dose equivalent absorbed by the personal dosimeter is not sufficient for evaluating the H_E. An analysis must be made, for each type of practice, concerning the working place and consisting in the assessment of all its specific parameters, such as the activity of the emitting source, the spectral and angular distribution of the radiation field, location and displacements of the exposed person, source-person distance, operation times and geometrical configuration of the practice.

For some types of practices, the application of theoretical conversion factors will be enough for the evaluation of H_E (2). Other practices will require a simulation through the development of physical or mathematical models for the evaluation of the organ dose equivalent and of H_E. The last procedure has been selected and a mathematical model was developed based on the application of the Monte Carlo method to the transport of photons in an anthropomorphous phantom.

A gynecological practice was recently considered by Eckerl, H.(3) In our case, a different procedure for the same practice was selected, where the H_E resulted from the application of the model. Both results were finally compared.

DESCRIPTION OF THE PRACTICE

An analysis was made of a gynecological practice consisting in the implantation of Ra-226 sources in utherus. This practice is usually performed by a gynecologist, an assistant, an instrumentist, a nurse and a physicist. During the therapy, all those occupationally exposed remain behind a 5 cm-thick lead shield and are mainly exposed in upper limbs, head and upper trunk.

The H_E absorbed by the gynecologist during a given implantation was assessed by means of an exposure mathematical model. This model is based on the analysis of a working place performed during actual implantations at the Krankenhaus München-Schwabing. A 100 mg Ra-226 punctual source is considered and the exposure is decomposed into four components called A, B, C and C'. Component A is related with the initial handling of the source, which lasts 5 seconds. Component B occurs during the implantation of the source in utherus, as the gynecologist works seated behind the lead shield for a period of 2.75 minutes. Component C takes place at the end of the application, when the physician stands up and remains standing in front of the patient for 1 minute, while the physicist performs control measurements in rectum and bladder. For comparison purposes, the results that would be obtained if the physician were sitted behind the shield have been considered as a fourth component, C'.

MATHEMATICAL MODEL

The dose equivalent distribution in the human body and the H_E were assessed by developing a code through the application of the Monte Carlo method to the transport of photons in a MIRD V phantom. The code was based on Kramer's code (4).

The history of each photon started by making it to fall upon a mathematical cylinder surrounding the phantom. In this way, a simulation is made of the interactions suffered by the photon in its way through the air from the source to the phantom surface.

The interaction point was selected through the usual procedure:

$$l = -\frac{\ln r}{\mu_0}$$

where:

r: is an alleatory number uniformly distributed between 0 and 1.

μ_0: is the total linear attenuation coefficient.

The difficulty caused by the various regions of the phantom in the choice of the mean free path was solved by applying Colemann's technique(5). A statistic weight factor was introduced for allowing the photon survival and its value was reduced after each interaction as per the following expression:

$$W_n = W_{n-1} \frac{\mu_{co}\ (E_{n-1})}{\mu_T\ (E_{n-1})}$$

where:

W_{n-1} and W_n : are statistical weights for the $(n-1)^{th}$ and the n^{th} collisions.

μ_{co} and μ_T : are Compton and total attenuation coefficients.

The photon was forced to continue with its history, with Compton interactions, and then, the energy and the direction cosines of the outgoing photon were calculated. The history of the photon comes to an end if it escapes from the phantom, if its energy is lower than a given threshold or if the statistical weight is lower than a given minimum value. In the latter case, an additional correction of the weight, as described by Kramer, R.(2), was performed. When the energy of the photon is higher than 1,022 MeV, 2 photons of 0.511 MeV are generated at the interaction point and the histories of these two photons are analyzed independently.

The energy, E, deposited in the n^{th} interaction was calculated as follows:

$$E^{(n)} = W_{n-1} \left[\frac{\mu^{Ph}\ (E_{n-1})}{\mu^{T}\ (E_{n-1})} E_{n-1} + \frac{\mu^{Co}(E_{n-1})}{\mu^{T}\ (E_{n-1})} (E_{n-1}-E_n) + \right.$$

$$\left. \frac{\mu^{PP}\ (E_{n-1})}{\mu^{T}\ (E_{n-1})} \ (E_{n-1} - 1{,}022\ \mathrm{MeV}) \right]$$

in which μ_{Ph} (E_{n-1}), μ_{Co} (E_{n-1}), μ_{PP} (E_{n-1}) and μ_T (E_{n-1}) are the mass-attenuation coefficients for the photoelectric, Compton, pair-production and total processes previous to the collision at the site considered, respectively.

The code considers the particular geometry of the practice and of the Ra-226 source. The initial energy of each photon introduced is obtained by comparing an alleatory number with the accumulated probability of the various spectral lines emitted by the Ra-226 source. The geometrical consideration corresponding with each one of the components A, B, C and C' in Table 1 are taken into account independently. Thus an evaluation is performed of the various contributions to H_E in the gynecological practice.

The H_E was calculated by means of the following equation:

$$H_E = \Sigma_T W_T H_T$$

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 were used in this work(5).

H_T is mean dose equivalent in tissue T.

The H_E absorbed by the gynecologist during the therapy may be assessed by means of the following superposition:

$$H_E = H_E^{(A)} + H_E^{(B)} + H_E^{(C)}$$

Since H_E, as defined by ICRP 26 (1), is not additive, its value was calculated by using a fixed-remainder model composed by thymus, SI, ULI, stomach and livér. Thus, the total H_E may be expressed as a superposition of the H_Es due to each component, A, B and C or C'.

RESULTS

The mean organ dose equivalents obtained for components A, B, C and C' are shown in Table 1.

Table 1

Mean organ dose equivalent (mrem)

Tissue	A	B	C	C'
Testes	$<$ 0.10	2.02	0.70	0.73
Lungs	$<$ 0.10	0.77	2.44	0.28
Red Bone marrow	$<$ 0.10	1.29	2.10	0.47
Thyroid	$<$ 0.10	8.01	2.03	2.91
Bone surface	$<$ 0.10	1.29	2.10	0.47
Skin	$<$ 0.10	2.74	2.09	0.99

The variation coefficients obtained depend on the size of the organ, the maximum value being 15% for testes and thyroid. The H_E absorbed by the gynecologist is shown in Table 2.

Table 2

Effective dose equivalent

Components	H_E (mrem)
A + B + C	4.3
A + B + C'	2.7

CONCLUSIONS

A comparison was made between results obtained from our model and the assessments made by Eckerl, H.(3). The difference between the H_Es absorbed by the gynecologist was only 16%, indicating a very good correlation, considering the associated errors.

On the other hand, it must be noted that the H_E absorbed by the gynecologist may be reduced in a 1.6 factor, if the physician remains sitted behind the shield while the physicist performs the control measurements. Such factor was obtained by comparing the H_Es obtained independently considering exposure components C and C'.

The developed exposure Monte Carlo model, considering the spectral and angular distribution of the field, the irradiation geometry, the superposition of components A, B and C or C' and some other specific parameters, allows for a correct simulation of the gynecological practice under analysis.

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