ANGULAR DEPENDENCE OF ORGAN DOSES AND EFFECTIVE DOSE FOR EXTERNAL PHOTON IRRADIATION

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ABSTRACT

Based on the new ICRP recommendations, the equivalent doses in organs and tissues and the effective dose were calculated using the Monte Carlo method for monoenergetic photons incident at each of 86 different angles. The results which were obtained for incident photon energies of 45, 90 and 1250 keV are demonstrated and the angular dependence of these dosimetric quantities is also discussed.

INTRODUCTION

The ICRP has, in its new basic recommendations[1], defined a new dosimetric quantity, the equivalent dose H_T, for radiation protection purposes with the newly introduced radiation weighting factor w_R. The ICRP has also amended the tissue weighting factor w_T and the definition of the remainder organs or tissues, which should affect directly the assessment of the effective dose E, previously called the effective dose equivalent H_E[2]. Since these new dosimetric quantities are expected to be different from the former ones, it is quite important to estimate them based on the method newly recommended. In addition, it is also worthwhile to make clear their characteristics to ensure the reasonable dose estimation in actual radiation protection practices. Since the quantity E cannot be measured, computer simulation is considered to be the best solution to estimate E at this moment. In the present work, the values of H_T in organs and tissues and E were calculated using the Monte Carlo method for external photon irradiations, and the results were analyzed to clarify their dependence on the radiation incident angle.

METHOD

The equivalent doses H_T for 61 different organs and tissues were calculated for external photons using a revised version of the DEEP code[3] in which the MORSE-CG code[4] is incorporated to calculate the radiation transport. Used was a MIRD-5 type phantom[3),5)], defined by mathematical formulae and with limited number of human media with different elemental compositions and densities: soft, lung and skeletal tissues. The photon cross sections were taken from the DLC-15 library[6] and the photon energy from 5 to 12000 keV was collapsed into 24 groups. The kerma approximation was employed for dose calculation, which is considered to give a good approximation for photons of energies less than several MeV. While three kinds of human media were used in the photon transport calculation, the red and yellow bone marrow tissues were added to them in the dose calculation. One of the biggest problems in calculating E with the MIRD-type phantoms is that they do not have the oesophagus. Hence the phantom was modified to have the oesophagus which was represented by an elliptical normal tube descending along the spine from the neck to around the diaphragm and an inclined tube attaining to the upper part of the stomach. The effective dose E was evaluated as a sum of weighted doses, $\sum_T w_T H_T$, with a set of the values of w_T specified in the new recommendations. The value of the w_T of 0.05 was allocated to the dose averaged over organs and tissues specified as the remainder by the ICRP.

The dose calculations were performed for monoenergetic photons incident in parallel beams at each of 86 different angles, defined at the spherical lattice points including both poles. Three photon energies were selected: 45, 90 and 1250 keV. All the calculated results were given as the values per unit absorbed dose to air in free air.

RESULTS AND DISCUSSION

From a number of calculated results, some typical examples are shown in this paper. The statistical error (one relative standard deviation) of the results is less than 5% for H_T and less than 3% for E.

The angular dependence of weighted equivalent doses ($w_T H_T$) relative to the horizontal axis of the human body is shown in Figure 1 for the gonads, red bone marrow and breasts for the incidence of 90 keV photons. The equivalent doses for these organs have a symmetric response with respect to the anteroposterior axis, reflecting their symmetric configuration in the human body.

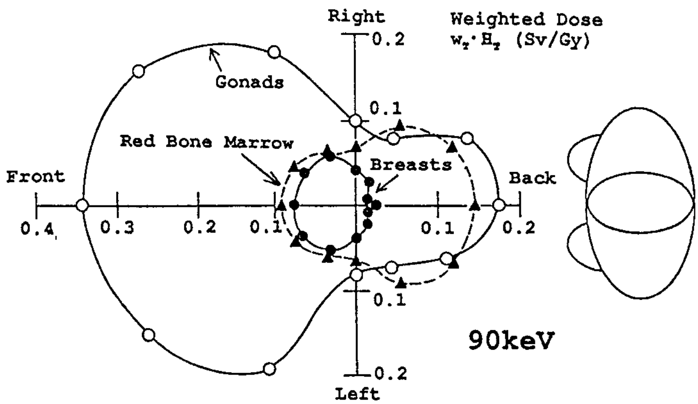

Figure 1. Angular dependence of weighted equivalent doses ($w_T H_T$) per unit absorbed dose to air in free air, relative to the horizontal axis of the human body for the gonads, red bone marrow and breasts. Incident photon energy is 90 keV.

An enhanced response for the photons from the front-half-around angle can be observed for the gonads and breasts. It is quite reasonable considering their location in the body. On the contrary, the red bone marrow has a slightly higher response for the back-half-around angle and it can be explained by its high content in the spine and pelvis. From observation of angular dependence of $w_T H_T$ in organs for all the 86 incident angles, it can be concluded that the gonads provide a dominant component of E, especially for the photons incident from the forward 2π solid angle.

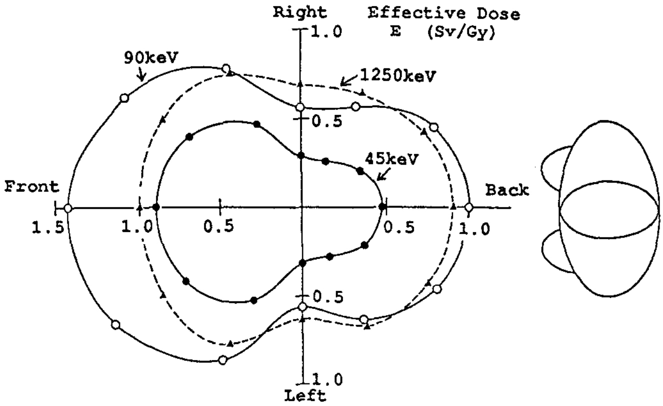

Figure 2. Angular dependence of the effective dose per unit absorbed dose to air in free air, relative to the horizontal axis of the human body for the photons of 45, 90 and 1250 keV.

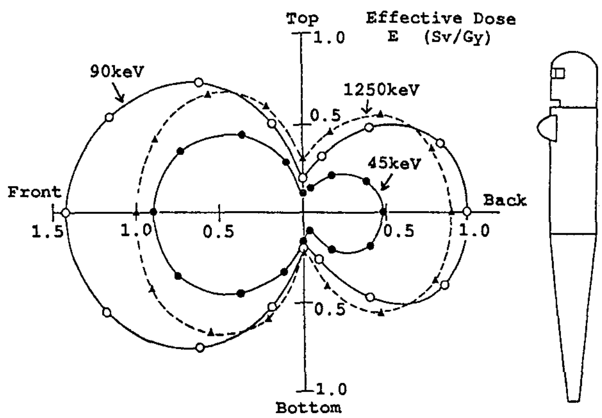

Figure 3. Angular dependence of the effective dose per unit absorbed dose to air in free air, relative to the vertical axis of the human body for the photons of 45, 90 and 1250 keV.

Figures 2 and 3 shows the angular dependence of E relative to the horizontal axis and vertical axis of the body, respectively, for the photons of 45, 90 and 1250 keV. In Figure 2, a symmetric response of E can be observed with respect to the anteroposterior axis in spite of asymmetric configuration of some organs such as stomach and liver. In Figure 3, an extremely depressed response of E can be seen for the photons incident from the top and bottom. This is because the principal organs are located at around the center of the body and they are shielded by the human tissue against the photons incident from such angles. Observing these two figures, it can be said that while the angular response of E for low energy photons, at 45 keV, appears enhanced in the forward 2π solid angle, the response becomes more and more isotropic with increasing the photon energy. It can be pointed out as an important characteristics of E that the response of E appears most enhanced for the photons incident at the just front angle for external photon exposure. It suggests that dosimeters worn at the surface of the front trunk gives the best indication in the general situation of personal monitoring. Finally, Figures 2 and 3 suggest also a need of special measures to monitor the dose for the photons incident from the top and bottom.

CONCLUSIONS

The equivalent doses H_T in organs and tissues and the effective dose E were calculated using the Monte Carlo method for external photon irradiations. The angular dependence of these dosimetric quantities was analyzed with the calculated results. A significant angular dependence is observed in both H_T and E. An interesting characteristics is that E appears most enhanced for the photons incident at the just front angle.

REFERENCES

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