QUANTIFICATION OF THE RISKS OF MEDICAL EXPOSURE IN X-RAY DIAGNOSTICS AND NUCLEAR MEDICINE

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INTRODUCTION

Medical irradiation of the human body occurs in diagnostic X-ray procedures, diagnostic nuclear medicine by internally administered radionuclides, and in radiation therapy. In many countries, medical exposure gives the largest man-made contribution to the population dose. Quantification of risks from medical irradiation is, however, a controversial and difficult question, which has been discussed a lot during recent years (1-8). The risk can be quantified either by using different weighted dose concepts, or by making estimates of the expected number of fatal tumors induced by ionizing radiation.

RISK ESTIMATES FROM DIAGNOSTIC X-RAY PROCEDURES

Exposures from diagnostic X-ray examinations can cause various stochastic biological effects. Genetic effects will be expressed in the descendants of the patient, and somatic effects in the exposed individual. The risk estimates for medical exposures deal therefore both with the induction of genetic effects and the induction of malignant diseases, which contribute the main somatic effect.

Cancer mortality risks for specific sites have been estimated by the US National Academy of Science's BEIR Committes 1972 and 1980, UNSCEAR 1977, and ICRP in 1977 . By using the factors of risk and the average dose equivalent for each organ and tissue, it is possible to estimate the expected total radiation risk involved in each medical diagnostic procedure.

The radiation risk expressed as the number of fatal tumours induced by ionizing radiation in a medical examination of type "j" can be assumed to follow a linear dose-resonse relationship as long as the radiation doses are low (<1 Gy). In this low dose range, the risk of an examination of type "j" can be given by the linear expression:

$$\mathrm{RISK}(j) = \sum_{t} \overline{H}(j,t) \cdot b(t)$$

where: $\overline{H}(j,t)$ is the average dose equivalent (Sv) in a tissue, "t" and b(t) is the risk factor for that tissue per 10 000 man-Sv.

A large amount of data for the dose-equivalent in different organs and tissues are required to be able to make accurate risk estimates for diagnostic X-ray examinations. Such data are, however, only seldom available in practice. Only a few extensive studies are available in the literature (6,7,8). There is, however, a good correlation between the risk estimates obtained from summing up the risks for specific organs and the energy imparted "E" (3,4,5).

FIGURE 1 gives the risks for various types of diagnostic x-ray examinations with the limits for males and females corresponding to the expression below. Although there is a rough averaging involved in the estimation of the riskfactors most examinations fall into the area covered by the equations:

$$RISK(male) = 0.23 \cdot E$$

$$RISK(female) = 0.40 \cdot E$$

where: "RISK" is cancer mortality per million of examinations and "E" is the energy imparted per examination expressed in mJ.

RISKS FROM DIAGNOSTIC NUCLEAR MEDICINE

The same procedure of correlating the estimated stochastic risk and the energy imparted in nuclear medicine examinations results in a wider spread of the ratios between risks and the energy imparted. The correlation between risk estimates obtained from summing up specific organ risks and the energy imparted, obtained by multiplying the average whole-body dose with a body weight of 70 kg, is shown in FIGURE 2. This diagram indicates at least two groups of relationships: One relationship is found for I-131 iodide for thyroid examinations, and another relationship is found for all other radiopharmaceuticals, lying well within the same area as the X-ray examinations. This indicates that the energy imparted might also be a useful risk estimator in nuclear medicine.

THE EFFECTIVE DOSE-EQUIVALENT

The concept of effective dose-equivalent is used in order to estimate a total risk which is equal if the whole body is irradiated uniformly, or if there is non-uniform irradiation of the body. The effective dose-equivalent is defined according to the ICRP by the equation:

$$H_E = \sum_t \overline{H}(t) \cdot w(t)$$

where: $w(t)$ is a weighting factor representing the proportion of the risk resulting from tissue "t" to the total risk valid when the whole body is uniformly irradiated. $H(t)$ is the dose-equivalent in an organ or tissue of type "t". The effective dose-equivalent thus calculated for various types of diagnostic X-ray examinations are given in references 7 and 8.

DISCUSSION

For those individuals exposed to medical irradiation, it might be of interest to know the expected individual risk for a specific type of examination. The expected individual risk will, however, depend very strongly upon the age and sex of the individual in question. The use of the effective dose-concept for this purpose would, therefore, be somewhat confusing. The expected individual risk, "EIR", can be derived from summing up the risk for each exposed organ, weighted by the relative malignancy expectancy factor, which takes the sex and age of the individual into account (4).

REFERENCES

(1) PERSSON, B.R.R.,"Medical irradiation and the use of the Effective Dose Equivalent Concept", 5th Internat. Congress of IRPA, Book of Papers, Vol. I, Pergamon Press, Oxford, (1980) 155.

(2) PERSSON, B.R.R., "Review of various weighted dose concepts used for estimation of risks from medical X-ray diagnosis", In: Patient Exposure to Radiation in Medical X-ray Diagnosis. Commission of the European Communities, EUR 7438EN, Luxemburg (1981).

(3) WALL, B.F., SHRIMPTON, P.C., "Deliberations on a suitable quantity and technique for assessing the somatic risk for diagnostic radiology", In: Patient Exposure to Radiation in Medical X-ray Diagnosis. Commission of the European Communities, EUR 7438EN, Luxemburg (1981).

(4) Wall,B.F., "A possible method for estimating of somatic doses from diagnostic radiology and Nuclear Medicine", Presented at British Institute of Radiology Congress , April 15-16, (1982).

(5) PAULY, P., "Stochastic late effects after partial body irradiation in diagnostic radiology: Evaluation of approximative data". Rad. and Environ. Biophys. 15 (1978), 21.

(6) BENGTSSON, G., BLOMGREN, P.G., BERGMAN, K., "Patient exposures and radiation risks in Swedish diagnostic radiology". Acta Radiol. Oncol. 17 (1978), 81.

(7) HASHIZUME, T., MARUYAMA, T., NODA, Y., IWAI, K., NISHIZAWA, K., TATENO, "Stochastic Risk Estimation from Medical X-ray Diagnostic Examinations. 2. Risk Estimates of Individuals from x-ray Diagnosis". Nippon Acta Radiol. 41 (1981),59.

(8) JANKOWSKI, J.,"Evaluation of the risk of neoplasm induction in the Polish population in result of X-ray radiation applied for medical purposes".(in Polish) Studia Materialy Monograficzne No.3, Lodz, Poland (1980).

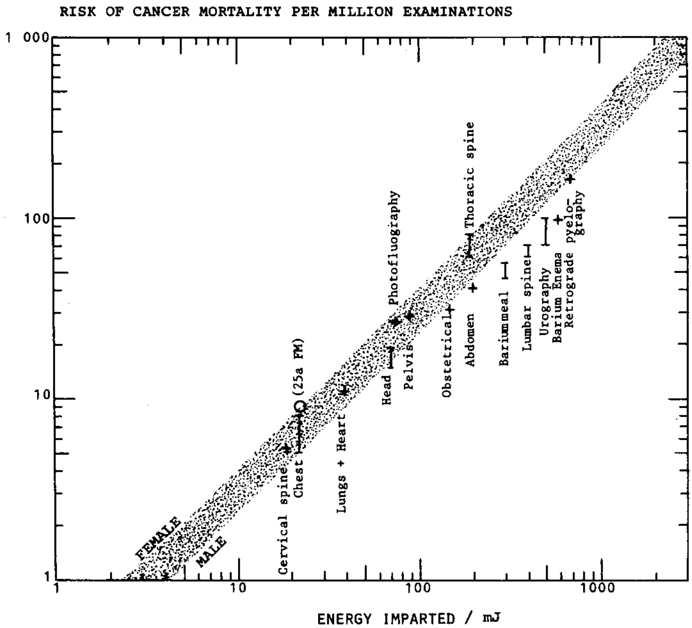

FIGURE 1. The correlation between the expected risk per million examinations and the energy imparted (mJ) for various types of diagnostic X-ray examinations.

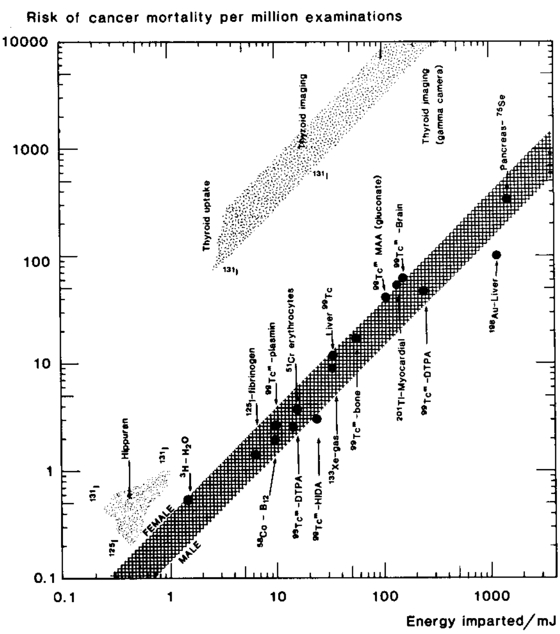

FIGURE 2. The correlation between the expected risk per million examinations and the energy imparted (mJ) for various radio-pharmaceuticals used in diagnostic nuclear medicine procedures.