SOMATIC DOSE INDEX IN RADIOLOGICAL EXAMINATIONS

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INTRODUCTION

The risk involved in X-ray examination for an individual and a population can be described with different indices. For the determination of these indices doses resulting from the X-ray examination are needed for organs particularly sensitive to radiation. Epidemiological investigations show the thyroid gland, the lungs, the breasts and the bone marrow to be organs sensitive to radiation. The dose delivered to them is generally considered in calculating the somatic dose index, which is used to describe the somatic risk. The somatic dose index can be defined as an effective uniform whole body dose which has the same somatic detriment as the set of non-uniform doses absorbed by the individual organs /6/. When studying a somatic dose index, the other tissues can, in addition to the above-mentioned organs, be considered as an organ group of their own /6/, for which a whole body dose is used as an organ dose.

CALCULATION OF ORGAN DOSES AND SOMATIC DOSE INDEX

In the present study, the dose assessment is based on the experimental formulae for radiation output, backscatter factor, depth dose curve and off-axis scatter used in the literature /6,10/. The formulae for backscatter factor and off-axis scatter were corrected in order to get a better agreement with experimental results. The energy imparted for calculation of whole body dose is obtained by summing up the doses along the central axis as presented by Carlsson /2/. The addition to the energy imparted resulting from the radiation scattered outside the primary field, is corrected by multiplying by the coefficient 1.12. The coefficient has been obtained by comparing the energy imparted computed with this program with the energy imparted computed by the Monte Carlo method /13/.

With this program, doses can be computed in individual points or as organ doses, whereby the doses of the major organs are computed when needed by means of several measuring points as a weighted average. In the red bone marrow there are 18 measuring points and the weighting factors are determined according to bone marrow distribution for adults /4/ and for children /3/. The 10 measuring points of the lungs and the 6 points of the chest have been regarded as being of equal weight. The doses of the ovaries, the uterus, the testes and the thyroid gland are calculated with one measuring point. The co-ordinate system used in the calculation program is placed at the surface of the phantom closest to the X-ray tube in the direction of the exposure.

The adult sizes can be changed as a function of weight /12/. Of the adult co-ordinates, the depth co-ordinate alone is transformed, because the organ locations in the other two directions are assumed to remain the same and only the depth increase or decrease as compared with the basic co-ordinate system changes.

To determine children's radiation doses, the program transforms the organ co-ordinates according to body size and age. The vertical co-ordinate is transformed by means of the sitting height /8/, because the sitting height describes the change in the organ location better than the full height, since in childhood the growth of the lower extremities is more pronounced than that of the body. The other two co-ordinates are transformed by means of the mean circumference /12/. The thickness and width are computed from the circumference based on the child's age by approximating with an ellipse, whose axes are computed.

The somatic dose index is calculated by means of the formula /7/

$$I_D = \frac{\Sigma S_i \alpha_i D_i}{\Sigma_i S_i \alpha_i} \quad , \text{ where}$$

i indicates the organ, S_i the relative severity of somatic effect, α_i the risk coefficient for the effect in organ i and D_i organ dose. The somatic dose index for men is computed from the doses of the red bone marrow, the thyroid gland, the lungs and the whole body. For women the dose received by the breasts is also considered.

The lung tissue absorption, which is smaller than that of the other tissues, was considered in computing doses in the lung measuring points directly involved in the primary field.

The dose computation does not consider the dose decrease due to bones in the separate measuring points, because the locations and thicknesses of the bones are not determined in the co-ordinate system used. When determining the bone marrow dose, the absorption in the bone was thought to be offset by the approximately 10 % additional dose owing to the photoelectrons emitted from dense bone.

The calculated depth doses, backscatter factors and off-axis scatter were compared with experimental values presented in literature /1,5,14/ and the calculated organ doses, energy imparted and somatic dose indices with values calculated with the Monte Carlo method /7,11,13 /.

Table 1 shows the somatic dose indices of some roentgen examinations calculated by the dose program presented here and the Monte Carlo method /6/.

The somatic dose indices and organ doses, however, can be compared only for their order of magnitude, because, apart from the sources of error in the application of computation model functions, differences are caused by the exposure values and co-ordinates, which may differ from those used by Rosenstein.

Table 1. Somatic dose index for some X-ray examinations compared with the values calculated by Laws et al. /7/. Total filtration is 3.75 mmAl.

Examination	kV	mAs	Field area cm^2	FSD cm	Somatic dose index this study male mrad/R*	this study female mrad/R*	Laws et al. male mrad/R*	Laws et al. female mrad/R*
thorax AP***	120	5	30x30	180	223	539	243	520
thorax PA***	120	5	30x30	180	206	139	231	169
vertebrae** (th)	73	100	15x29	84	115	100	149	412[1]
vertebrae** (lumbal)	70	80	17x21	82	45	29	73	39
pelvis**	72	63	29x23	75	69	36	57	30
hip**	72	52	12,5x18	90	24	13	24	12

*** HVL 4 mmAl
** HVL 3 mmAl
* dose indices are presented against 1 R measured free in air at fokus-skin distance mrad = 10^{-2} mGy
1) broad field

EXPERIMENTAL VERIFICATION

The doses obtained with the dose computation program were compared with the doses obtained from the X-ray examination simulations made with anatomical slice phantom measurements (Alderson-Rando phantom) and inserted LiF (TLD-100) thermoluminescence dosimeters. Measurements were made in pelvic, hip, pelvimetry and gastrointestinal examinations. The doses computed at the different phantom points for these X-ray examinations and the doses measured with the TL dosimeter at the corresponding points were compared with each other. The mean and S.D of the relation of the computed and measured doses were about $1.3 \pm (0.3 \pm 0.6)$ for all points. For the points middle in the primary field the agreement was still better.

The substantial differences in doses in some single measuring points are generally explained by the fact that the points are close to the field border, which even with a minor deviation in the definition of field location results in a major change in the dose computed due to the substantial dose diminution in the border area. Moreover, bones may reduce the measured dose, but the dose computation program does not consider the bone absorption.

DISCUSSION

For collective dose determinations the present calculation method can be regarded as sufficiently good, because the most noteworthy errors are made, not in dose calculations, but in incorrect or insufficient initial data, i.e. basic phantom model, exposure values, number of examinations, size, age and sex distribution of patients and so on. Another question is whether the energy imparted alone would be more effective in describing the

patients' radiation impact. Some factors support this method. During the fluoroscopic examination many parameters (kV, mA, field site and size, number of exposures, fluoroscopic time) may vary making it impossible to record all the data needed for organ dose calculation. The only exact method to determine the true patient radiation impact is to measure area exposure with a calibrated area exposure monitor and calculate the energy imparted. Besides, in some cases the whole body dose alone comprises a large part of the somatic dose index.

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