ORGAN DOSES AND INTEGRAL DOSES IN X-RAY DIAGNOSIS OF THE CHEST AND OF THE HEAD

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1. INTRODUCTION

The basis for the evaluation of the somatic risk due to the exposure in x-ray diagnosis is the knowledge of the organ doses and the integral doses in the patient and the knowledge of their frequency and distribution in the population. The dose measurements presented in this paper are concerned with the dose distribution and the integral doses (energy imparted) of standard x-ray examination of the chest and of the head by radiographic films. These types of examination are most frequently done in diagnostic radiology. They probably contribute to a large degree to the radiation exposure and to the somatic risk due to diagnostic radiology.

2. EXPERIMENTAL SEKTION

2.1 X-ray generator

The radiation source was a x-ray tube P 125/20/40 (Siemens AG., Erlangen, West Germany). The voltage was generated by a two peak generator (Ergophos 2, Siemens AG., Erlangen, West Germany). The maximum voltage respectively short time tube current is according to the manufactures 125 kV and 100 mA. The inherent filtration of the x-ray tube and the light beam localizer was equivalent to 2 mm Al.

2.2 Phantom

The dose distribution was measured in an Alderson-Man-Phantom corresponding to an "average man" with a mass of 73.5 kg and a length of 175 cm. The phantom, developed for radiation therapy, allowed the measurement of the dose distribution in a three dimensional network with a width of mesh of 3 cm in transversal and 2.5 cm in axial direction. For one exposure from 200 to 1000 LiF dosemeters were distributed in the phantom.

2.3 Dosimetry

Cylindrical LiF-rods of 6 mm length and 1 mm diameter from Harshaw Company, Solon, Ohio, USA, were used. The rods were introduced into a special cylindrical detector holder from lucite of 25 mm length and a diameter of 6 mm. The LiF-rods enclosed in lucite were calibrated for all radiation qualities used by comparison with a thimple ionizing chamber (Siemens Universaldosimeter), calibrated at the "Physikalisch-Technische Bundesanstalt" in Braunschweig, West Germany. The tissue dose was measured by recording the LiF-thermoluminescence of the dosemeter using the Harshaw 2000 instrument.

2.4 Evaluation of the mean organ dose and the total energy imparted (integral dose)

The mean organ or tissue doses and the total energy imparted (integral dose) for each of the four types of x-ray radiographs (see Table 1) were obtained from the corresponding three-dimensional dose matrix in the phantom by integration of the equation $dE_D = \rho D\, dV$, where dE_D is the energy imparted to the material in the volume element dV, D is the absorbed dose and ρ is the density of the material in this volume element. The integral extends over the volume V of the organ, the tissue, or over the "total body", taking into account the different volumes and densities ρ of the three types of tissue equivalent material - soft tissue with $\rho = 0.985\, g\, cm^{-3}$, lung tissue with $\rho = 0.32\, g\, cm^{-3}$, and bone tissue with $\rho = 1.45\, g\, cm^{-3}$ - and their distribution in the irradiated part of the body. For practical reason the integration was replaced by the sum over sufficient small volumes of the size of the mesh of the matrix, 3 cm x 3 cm x 2.5 cm, and the energy imparted to the material in the corresponding small volume.

2.5 Accuracy and precision

The relative accuracy of the absorbed dose D measured with a LiF-detector is 2.5% due to the uncertainty given in the calibration documents of the "Physikalisch-Technische Bundesanstalt" for the ionization chamber used for calibration of the LiF-detectors. There are variations in the sensitivity in repeated usages of the LiF-detectors and the dependence of their sensitivity on photon energy and beam direction and due to errors in calibration and reading. The precision of our repeated dose measurements in terms of the relative standard deviation was 7%. The error of the measurement of the disdance between focus and patient is negligibly. The reproducibility of the tube output due to errors in high voltage, current and time of the x-ray generator was 10%.

The relative accuracy of the evaluation of the mean organ or tissue doses and of the total energy imparted E_D due to the replacement of the integral of $dE_D = \rho D\, dV$ over a specified volume by a sum over volumes of about 3 cm x 3 cm x 2,5 cm and due to the irregular boundaries of the lung tissue and bone tissue in the exposed part of the phantom was estimated to be 3.5%.

The relative overall accuracy as well as the overall precision in terms of relative standard deviation was about 13%.

3. RESULTS

Table 1 gives energy imparted to the total body E_D in mJ for the different projections together with the condition of the exposure specified in the first column.

In Table 2 the energy imparted to the total body E_D for the radiographic examination of the chest for two beam qualities are given and compared with data obtained from the literature after "normalization" these literature data to the conditions given in Table 1. Beside the total energy imparted Table 2 gives data for the energy imparted to the thyroid as well as the mean dose $\bar{D}$ in the thyroid. The agreement between the data from the literature obtained by Monte Carlo calculation and our data obtained by measurement are good in case of the energy imparted to the total body. They differ more in case of the dose (and energy) in the thyroid because of the location of this small organ near the field edge and the corresponding known strong variation of the dose with small variations of the distance of the thyroid to the field edge (6). Considering this effect the agreement between the data for the thyroid is good.

Table 1

	SSD cm	mAs Product	Field Size[c] cm x cm	Entrance Exposure[d] mR	E_D[e] mJ
Skull LAT[a]	100	50	24 x 30	260	3.5
Skull PA[a]	95	50	24 x 30	280	2.1
Chest PA[a]	95	30	35 x 35	175	16
Chest PA[b]	120	8	35 x 35	40	

a: 75 kV, 2 mm Al, HVL 2.3 mm Al, no Grid
b: 120 kV, 4 mm Al, HVL 5.5 mm Al, W 5/50 Grid
c: at the film
d: free in air
e: preliminary values

Table 2

HVL mm Al	Body or Organ	Energy Imparted Lit. 4[b]	Lit. 5[b]	Own Measurements
2.3	Total Body	13.7 mJ	-	16 mJ
	Thyroid	0.30 µJ	0.63 µJ	1.0 µJ
		($\overline{D}^a$ = 15 µJ/kg)	(32 µJ/kg)	($\overline{D}$ = 50 µJ/kg)
5.5	Total Body	5.0 mJ	-	8.0 mJ
	Thyroid	0.29 µJ	0.80 µJ	0.32 µJ
		(14 µJ/kg)	(39 µJ/kg)	($\overline{D}$ = 16 µJ/kg)

a: $\overline{D}$ mean organ dose, 1 µJ/kg = 0.1 mrd,
b: extrapolated from Lit.4 and 5

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