ASSESSMENT OF ORGAN AND TISSUE DOSES FROM COMPUTED TOMOGRAPHY EXAMINATION

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INTRODUCTION

Computed tomography examinations greatly contribute to the collective dose from diagnostic radiology. This is caused by increase in CT examination frequency and relatively high level of patient irradiation. Advances in design of CT scanners give better quality images but at the cost of increased patient exposure. Organ and tissue doses from CT examinations are usually assessed by Monte Carlo method and mathematical phantom (1). In this work anthropomorphic Alderson phantom and thermoluminescent detectors were used. Particular attention was paid to brain examination. In many CT installations the gantry is tilted during brain examination in order to limit eye lens exposure. M C method can not simulate this and as the result the eye lens and thyroid doses obtained by both methods differ considerably.

METHOD

The study was carried out using five different CT installations: CT/T 8800, CT 9800 and CT MAX made by General Electric; SOMATOM 2 made by Siemens and CT 1200 SX made by Picker. Five most frequent CT examinations were selected: brain, axial orbits, lung, liver and abdomen-pelvis (2). Lithium Fluoride (TLD-100) thermoluminescent dosemeters (3.2x3.2x0.9 mm) were used. They were read on Toledo 954 reader. Quality of the X-ray beam characterized by half value layer (HVL) and kVp value was measured for each scanner. The data were later used for TLD calibration procedure. Obtained values were:a.) HVL=8.5 mm Al, kV_p=125 kV for SOMATOM 2 and b.) HVL=5.5 mm Al, kV_p=120/130 kV for other scanners. Calibration was carried out in a water phantom with 0.6 cm^3 Farmer ion chamber type 2571 as a reference dosemeter. Correction factors from water to ICRU muscle and compact bone were calculated from conversion factors (3) for both X-ray qualities: a.) $f_m/f_w = 1.02$, $f_b/f_w = 3.06$; b.) $f_m/f_w = 1.26$, $f_b/f_w = 3.65$. Settings of nominal slice thickness and exposure (mAs) recommended by each manufacturer for each examination were used. Dose distribution resulting from CT exposure was measured in the phantom at the central part of irradiated area and these data were used for mean dose estimation to organs extending through many phantom slices (4). Since Alderson phantom is made close to Average Man specifications the results are expected to represent mean organ doses for patient of similar specifications.

RESULTS

Operating parameters of CT scanners for two groups of examinations are given in two tables. Organ doses are given in tables for each examination. Dose to skin is measured as local dose in the irradiated area. Red bone marrow is marked as RBM. Organs with doses less than 0.05 mGy were excluded. Radiation field limits for each examination are shown on figures adjacent to tables with organ dose results.

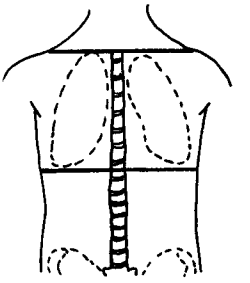
OPERATING PARAMETERS FOR LUNG AND ABDOMEN-PELVIS EXAMINATIONS

Scanner	Slice width (mm)	Lung examination		Abdomen - pelvis examination	
		Exposure settings (mAs)	Number of slices	Exposure settings (mAs)	Number of slices
CT 8800	10	288	23	368	22
CT 9800	10	420	23	510	21
CT 1200	10	240	20	330	20
CT MAX	10	365	24	365	20
SOMAT 2	8	230	31	330	24

For lung examination somatic risk is due to the dose to lungs, breast, bone surface, RBM and oesophagus lying in direct X-ray beam. Considerable scattered radiation dose is to the thyroid , liver and stomach. Genetic risk is minimal due to large distance from gonads to the radiation field.

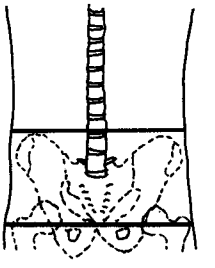
MEAN ORGAN DOSES (mGy) FROM LUNG EXAMINATION

Organ	CT 8800	CT 9800	CT 1200	CT MAX	SOMAT 2
Lung	14.4	33.5	26.6	28.6	26.0
Breast	10.4	26.0	38.7	35.1	37.4
Thyroid	1.4	10.1	4.7	7.2	4.3
Bone surface	1.8	6.3	4.9	5.3	5.3
RBM	2.9	9.9	7.8	8.4	8.4
Oesophagus	11.8	25.7	28.5	28.7	22.6
Liver	3.8	9.8	10.1	10.5	8.5
Stomach	2.7	6.9	7.1	7.4	6.0
Skin	10.9	33.4	32.6	27.0	32.5



MEAN ORGAN DOSES (mGy) ABDOMEN-PELVIS EXAMINATION

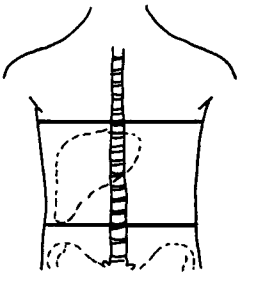
Organ	CT 8800	CT 9800	CT 1200	CT MAX	SOMAT 2
Colon	7.1	36.9	27.5	37.4	19.4
Liver	< 0.05	3.1	3.4	2.8	1.7
Stomach	< 0.05	5.4	5.8	4.9	2.8
Bladder	10.3	24.7	38.6	25.2	25.7
Uterus	10.0	24.0	36.7	25.0	25.3
Ovaries	10.3	24.7	38.6	25.2	25.7
Testes	1.6	2.7	6.5	5.9	3.5
Bone surface	2.2	7.6	9.2	6.5	5.6
RBM	3.7	13.2	16.0	11.7	9.7
Skin	12.8	41.0	56.4	30.0	44.3



Considerable genetic risk from this examination is due to high dose to ovaries which are subjected to direct X-ray beam. Testes with male patients are subjected to scattered radiation. Uterus dose was measured to assess conceptus dose in case when a pregnant patient was subjected to abdomen-pelvis examination. Dose distribution data from abdomen-pelvis exam. were used to calculate organ doses from liver examination.

MEAN ORGAN DOSES (mGy) FROM LIVER EXAMINATION

Organ	CT 8800	CT 9800	CT 1200	CT MAX	SOMAT 2
Oesophagus	1.7	5.5	5.9	4.7	4.8
Liver	12.4	39.9	43.3	34.5	35.5
Stomach	12.2	39.0	42.1	33.4	34.1
Bone surface	0.7	2.4	2.6	2.1	3.4
RBM	1.2	3.8	4.1	3.3	3.4
Skin	12.8	41.0	56.4	30.0	44.3

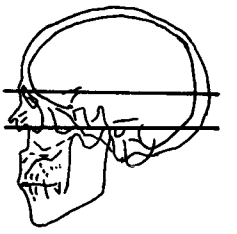


OPERATING PARAMETERS FOR BRAIN AND AXIAL ORBITS EXAMINATIONS

Scanner	Brain examination			Axial orbits examination		
	Slice width (mm)	Exposure settings (mAs)	Number of slices	Slice width (mm)	Exposure settings (mAs)	Number of slices
CT 8800	10	576	10	5	576	10
CT9800	10	600	10	5	420	10
CT 1200	10	240	11	3	300	10
CT MAX	10	365	11	2	365	12
SOMAT 2	8	518	13	2	518	14

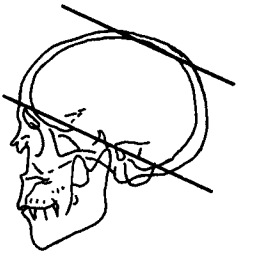
MEAN ORGAN DOSES (mGy) FROM AXIAL ORBITS EXAMINATION

Organ	CT 8800	CT 9800	CT 1200	CT MAX	SOMAT 2
Brain	0.3	0.4	0.2	0.3	0.3
Eye lens	26.2	43.5	36.1	41.0	52.6
Thyroid	0.3	0.3	0.3	0.4	0.5
Bone surface	0.7	1.3	0.7	0.6	1.0
RBM	0.8	1.5	0.8	0.7	1.1
Skin	19.1	46.3	30.7	31.7	49.7



MEAN ORGAN DOSES (mGy) FROM BRAIN EXAMINATION

Organ	CT 8800	CT 9800	CT 1200	CT MAX	SOMAT 2
Brain	25.7	47.8	30.7	36.6	40.3
Eye lens	9.4	13.0	19.0	9.9	9.2
Thyroid	0.6	0.5	0.4	0.6	0.8
Bone surface	1.9	3.6	2.3	2.7	3.3
RBM	2.1	4.3	2.6	3.0	3.6
Skin	23.0	55.5	28.8	33.7	48.2



COMPARISON OF DOSE TO THE EYE LENS (mGy) FOR THIS WORK AND (5)

	NRPB R-249		This work	
Scanner	Head	Axial orbits	Brain	Axial orbits
CT 8800	31.0	37.0	9.4	26.2
CT 9800	56.0	51.0	13.0	43.5
CT 1200	76.0	78.0	19.0	36.1
CT MAX	42.0	40.0	9.9	41.0
SOMAT 2	45.0	37.0	9.2	52.6

Comparison of dose to the eye lens for CT examinations of the head region done in this study and those obtained in (5) shows that results for axial orbits examination are reasonably close with the exception of CT 1200. The results for brain and head examinations differ considerably because of different irradiation geometry. In many CT installations the gantry is tilted during brain examination by about 20° and the eye lenses are outside the direct radiation beam. For other examinations the mean dose to organs completely covered by the primary X-ray beam measured in this work is between mean and maximum organ dose values obtained in (5) and corrected for mAs values. Dose to organs partly covered by primary X-ray beam is difficult to compare because it critically depends on radiation field limits setting by the radiographer.

CONCLUSIONS

Irradiation geometry should be specified when organ doses from CT head examination are reported to enable their comparison. Visualization of brain region in CT head examination does not have to involve eye irradiation. The eye lens dose can be kept resonably low by properly setting radiation field limits.

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