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Irradiation Dose to the Lens of the Eye During CT of the Head

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Summary. The irradiation dose to the lens of the eye during CT scanning has been measured in 16 patients. The dose is greatly influenced by changes in gantry angulation, the position of the patient, the thickness and number of slices, KV, and milliamperage. The total lens dose has been measured to be higher than previously reported. Repeated CT scans imply the risk of irradiation cataract, especially in infants and children.

Key words: CT scan – Eye lens irradiation dose – Cataract – Influence of patient positioning

CT of the head offers obvious advantages compared to the traditional neuroradiological examinations. Being an innocuous procedure, it gives rapid and reliable information about cranial pathology without much inconvenience to the patient. Accordingly CT of the head is an ideal examination in the pediatric age group and is also widely used for repeated follow-up examinations.

The following study is concerned with the measurement of irradiation, as influenced by different positioning of the patient, changes in gantry angulation, and slice thickness, factors which have not been analyzed previously. Measurement of lens dose is of special interest, considering the irradiation sensitivity of this organ and its exposure in lower head slices which often involve the orbits.

Material and Methods

CT of the head was performed with an Ohio Delta 25 unit, the tube moving in a semicircle below the supine patient.

The irradiation dose was measured in 16 patients by thermoluminiscense dosimetry using Fingerdos LIF (79) dosimeters. A dosimeter was set on each upper eyelid, attempting to place it just anterior to the lens. Gantry angulation (Fig. 1) was determined from the orbitomeatal line (OM). The gantry was angulated upwards (−) or downwards (+) in relation to this line as required.

The middle of the first, lowest, slice was placed at an adequate distance above or below the line determined by the angulation of the gantry according to the indications for the examination (Line Z, Table 1).

The measurements comprise total ("pile up") irradiation at the point of interest in the individual patient during the investigation, considering total dose – not the dose from a single scan – to be the factor of critical importance.

Results

The results of the dosimetry measurements in the 16 patients are shown in Table 1. Dependent upon the indications for the investigation and corresponding ad-

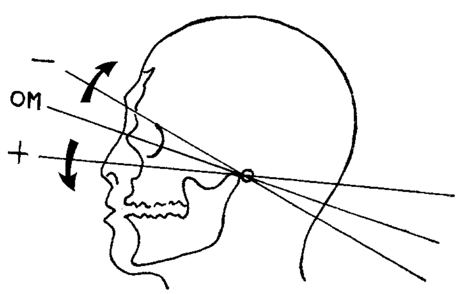

Fig. 1. OM: orbitomeatal line; −: direction of negative gantry angulation; +: direction of positive gantry angulation

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Table 1. Measurement of lens irradiation dose in 16 patients. 1. Z = middle of the lowest slice in relation to gantry angulation and orbitomeatal line measured in millimeters (mm). 2. one scan = two slices

Case no.	Case indication	Age years	Gantry angulation	Z	Slice thickness	Contrast	Slices with overlap	Total slices	mA	KV	Patient position	Right eye mSv	Left eye mSv
1	Retinoblastoma oculi dxt., control	2¼	+15°	+24mm + 8mm	8mm	+	8 12	20	30	130	Right side	312.9	304.8
2	Astrocytoma fossa post., control	2¾	+15°	− 5mm	8mm	+	20	28	30	130	Supine	184.4	152.4
3	Proces in left hemisphere (not found)	½	+10°	+10mm	8mm	+	–	24	30	130	Right side	177.8	123.0
4	Meningioma fossa post.	64	+15°	0mm −12mm	8mm	+	10 12	30	30	130	Supine	150.1	141.1
5	Tumor orbitae control	55	+15°	+15mm	8mm	+	12	12	30	130	Supine	112.1	103.8
6	Intracerebral absces	3¾	+20°	+15mm	8mm	+	–	12	30	130	Right side	96.4	55.6
7	Hydrocephalus control	½	+10°	+15mm	13mm	–	–	8	30	130	Left side	55.5	74.6
8	Hydrocephalus, obs. control	1	−10°	+15mm	13mm	–	–	8	30	130	Left side	47.3	70.3
9	Dilaceratio cerebri seqv. control	4¾	0°	+15mm	8mm	–	–	14	20	130	Left side	38.4	70.0
10	Prader-Willi syndrom	3½	−10°	0mm	8mm	+	20	44	30	130	Supine	63.3	51.5
11	Metastasis hemisphaerii sin.	63½	+10°	0mm	8mm	+	–	30	30	130	Supine	60.3	48.6
12	Hydrocephalus control	1½	+15°	+15mm	13mm	–	–	10	20	130	Right side	58.5	43.0
13	Hydrocephalus control	1½	+10°	+20mm	13mm	–	–	8	20	130	Left side	38.6	55.4
14	Retarded development	3	−10°	+15mm	8mm	–	–	14	30	130	Supine	11.7	12.8
15	Left-sided focal fits	5¼	−10°	+20mm	8mm	+	–	26	30	130	Supine	11.1	11.2
16	Porencephalia control	8½	−10°	+15mm	13mm	–	–	10	20	130	Supine	4.96	5.98

justments in examination procedure in relation to this, the total irradiation dose recorded at the level of the upper eyelids ranged from 4.96 mSv to 312.90 mSv[1].

It is seen (Table 1) that positive angulation of the gantry increases the lens dose considerably. And in addition, the dose is increased the lower the first slice is situated. Scans with overlap (slices of 4 mm thickness) performed in order to evaluate the more delicate changes in cerebral structure, give significant increment in irradiation dose, which furthermore may be doubled if the sections are repeated after the use of contrast intravenously. In the five patients (Table 1) in whom the examination has included slices with overlap, these slices are the most basilar ones.

Many of the CT scans of children have been performed with the child lying on his right or left side. In this position the child is usually calm, and a mild sedative (mebumal or diazepam) usually suffices to immobilize him during the examination. Not unexpectedly however, considering the construction of this scanning unit, it is seen from the measurements that the irradiation dose is markedly increased when the patient is in this position, in which the eyes are directly hit by the beam, the lower eye being the more exposed. In addition with the patient lying on his side, it is difficult to achieve an acceptable position of the patient without effecting a positive angulation of the gantry, which further increases the lens dose. Consequently we have constructed a special children's couch attempting to obtain a more appropriate position of the head.

It is also seen that an increment in width of the sections decreases the eye dose, due to the reduction of total number of slices. This happens in spite of an increase of scattered irradiation. Moreover a decrement of milliamperes used – from 30 to 20 – will reduce the dose, and this is effected without any visible deterioration of picture quality.

The minor differences in dose values recorded on the two eyes in the supine position may be explained by unequal positions of the dosimeters on the two sides, and perhaps a slightly oblique placing of the head in the individual patient.

Discussion

The measurements reported in the 16 patients with one CT scan show a wide range of irradiation dose to the lens, the highest value being about 60 times higher than the lowest. In similar measurements various authors have reported lens dose values from 5.0 to 8.5 mSv during CT scans [7, 12, 14] including special examination of the orbits [1]. Compared to our results these values are surprisingly low and at a level which was seen only in one of our 16 patients. The scan in this patient was performed using 130 KV, 20 milliamperes, only a few 13 mm thick slices and a negative gantry angulation, all optimal conditions in relation to irradiation dose.

Horsley and Peters [11] have pointed out that scattered irradiation from adjacent scans is not negligible and expect skull dose to be about 100 mSv during an ordinary examination with additional contrast series.

The dose also depends on the construction of the scanner and the level of information wanted. High resolution scans with thin slices will require more photons, attainable by decreasing scan speed and increasing milliamperage, both of which will augment irradiation dose. Consequently, in one examination without contrast, doses as high as 350 mSv may occur [13]. Brash et al. [8] have shown that significant changes in KV and milliamperes will produce only small differences in resolving power. It should accordingly be possible to reduce both of these factors and achieve a lower irradiation dose with only insignificant loss of image quality. The scan speed (79 s) and KV have been kept constant in our study.

The average irradiation dose received by the lens of an unprotected eye, while three projections are made for unilateral carotid angiography, has been reported to be as high as 170 mSv [2], a dose comparable to that found in Cases 1, 2, 3, and 4 of our study.

The great sensitivity of the lens to irradiation, especially in infants and children, has been pointed out by Merriam and Focht [3], who reported that cataract may occur from a dose that, in modern units, could be as low as 2000 mSv.

Consequently our findings warrant restraint in using repeated CT examinations within short intervals, particularly in children in whom, other things being equal, the total organ irradiation dose can be relatively higher than in adults compared to the dose received as a result of a conventional X-ray examination, since the same dose is applied to a smaller sized body [6].

In addition, relatively greater penetration of the photon beam through the small object may yield higher cumulative central and distal doses during the scan [8]. Furthermore the natural restlessness of the child will increase the rate of artefacts and the demand for reexaminations in the nonsedated patient [9].

The IRCP has extablished 300 mSv per year as the upper limit for eye lens dose in people working with ionizing irradiation [5]. This limit may be too high, and perhaps it should be as low as 150 mSv [4].

[1] 1 mSv = 100 mRem

Our study demonstrates an obvious risk when frequent and repeated CT scans are performed. Isherwood et al. [12] have shown that intensive neuroradiological examinations including CT may reach doses as high as 600 mSv. In conclusion, considering eye lens dose in the individual patient, due respect should be paid to the distance of slices from the eyes, gantry angulation, slice thickness, number of slices, Kv and milliamperage, keeping in mind the greater irradiation risk in infants and children.

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