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Assessment of Radiation Dose to the Lens of the Eye and Thyroid of Patients Undergoing Head and Neck Computed Tomography at Five Hospitals in Mashhad, Iran

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ABSTRACT

Introduction: In recent years, the number of computed tomography (CT) scans, which is a high-dose technique, has increased significantly. Head and neck CT is performed frequently and thyroid, particularly in children, has always been considered a sensitive organ. In recent years, radiobiologists and health physicists have been more concerned about the safety of lenses of the eyes, as cataract is no longer considered a deterministic effect.

Material and Methods: In the present study, incurred doses to the thyroid and lens of the eye of 140 patients who underwent common head and neck CT at five hospitals were measured by thermoluminescent dosimeters (TLD-100). The patients were divided into two age groups of pediatrics and adults. TLD chips were placed on the patient's skin surface. For each patient, scan parameters, sex and age were recorded. Exposed TLDs were read by a manual TLD reader.

Results: The average absorbed dose of the thyroid, as well as the lenses of the left and right eyes were 5.89±1.74, 15.84±2.81 and 16.25±2.57, respectively, for the pediatric patients and 5.00±1.17, 17.64±1.69 and 24.41±1.89 for adults. Patient-specific organ doses were influenced by the scanned region, scan protocol and patient's age.

Conclusion: In the present study, the mean eye dose was much lower than the 500 mGy threshold recommended by International Commission on Radiological Protection (ICRP) for lens of the eye damage, thus, it appears to be clinically safe. While CT scan remains a crucial tool, further dose reduction can be achieved by controlling different factors affecting patient doses.

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Introduction

Medical applications of ionizing radiation play a significant role in the diagnosis and treatment of patients worldwide, without which lives of many patients would be endangered. Nowadays, computed tomography (CT) scan, a high-dose technique, has been recognized as the largest component of man-made sources of ionizing radiation [1].

In spite of the well-established detrimental effects following exposure to ionizing radiation, ever increasing use of ionizing radiation is inevitable [2]. CT scan provides very high-quality images that reproduce transverse cross-sections of the body at the same time [3, 4]. Lee et al. in their study highlighted the significant contribution of CT examinations to public exposure. The figures are alarming, as a matter of fact, 260 million examinations are annually performed (in 2004), which constitute 67% of all medical radiation exposures [5]. CT examinations represent just over 44% of the global collective dose equivalent from medical radiation exposures [6, 7]. The extensive use of CT and growing concerns about increased radiation exposure is emphasizing the need for appropriate strategies to optimise and thereby, reduce radiation dose due to CT. It has been estimated that in the United States approximately 2% of annually diagnosed cancers are caused by ionizing radiation from diagnostic examinations, in other words, in future, 29000 cancer cases annually would be initiated by medical radiation exposures [8].

Depending on the prescribed CT scan, one or a few sensitive organs may be exposed to primary or scattered X-rays, such as ovaries in CT scan of the

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pelvis and thyroid and lens of the eye in CT scan of the head and neck region [6, 9, 10]. The primary beam radiation received by organs can be clinically justified. However, the dose received by the organs outside the primary beam cannot be justified when the organs are radiosensitive. The thyroid, eyes, breasts and gonads receive a higher proportion of radiation due to increased scatter radiation [8].

However, despite the established detrimental effects following exposure to ionising radiation, ever increasing use of ionising radiation is inevitable [2]. A rational approach to this “double-edge sword” phenomenon is to fully implement International Commission on Radiological Protection (ICRP) principles, namely justification, optimization and limitation. In a country, region, city or even a big hospital with several radiological facilities, established diagnostic reference levels (DRLs) would help individual facilities to keep in line with limits and the as low as reasonably achievable (ALARA) principle. Thus, monitoring patient dose in CT scan centres is particularly essential. In this context, sensitive organs deserve extra consideration to reduce various somatic and genetic radiation-induced risks [6, 9-11].

Materials and Methods

The radiation doses to the lens of the eye and thyroid of 140 patients who underwent common head and neck CT examinations at five hospitals in Mashhad, Iran, were measured. Four CT devices of Siemens-16 slice, Siemens-2 slice, Philips- 16 slice and Toshiba-16 slice were included in this work.

The protocols adopted in the study were brain (sequential and spiral), sinus (sequential and spiral), neck (spiral) and neck-brain (spiral). The scanning parameters of the protocols such as the CT dose index (CTDI), dose length product (DLP) for kilovoltage peak (kVp), tube current-exposure time product (mAs), pitch factor, sex and age for each patient were recorded.

Out of the140 patients examined, 39% were male and 61% were female. All the patients were divided into two age groups: 1.5 to 15 years for paediatric and > 15 years for adult patients.

Thermoluminescent dosimeters (TLD-100, LiF:Mg,Ti) were placed on patients’ skin at three different locations to measure absorbed dose by the thyroid and lens of the eye (two TLD chips on each eye lid and two TLDs on the thyroid surface). The TLDs used were 3.2*3.2*0.9 mm^3 in dimensions. TLDs were annealed based on the standard protocols recommended by the manufacturer at 400°C for 1 hour, then cooled at room temperature, and again heated at 100°C for 2 hours. To calibrate TLDs, the standard protocols established in our dosimetry laboratory (based on the approved protocols in the literature) were employed. TLDs were calibrated by irradiator 2210 (manufactured by Thermo Electron Corporation, USA). Irradiated TLDs (on patient’s body) were read after 24 hours, as recommended, by a manual TLD reader 3500 (Harshaw , USA).

Results

The employed parameters for different CT protocols for pediatric and adult patients are presented in Table 1. The average values of all scan parameters for various protocols and both age groups were determined.

Average doses of the thyroid and lens of the eye resulted from head and neck CT scan of both age groups are presented in Table 2.

Mean measured organ dose of adult and paediatric patients subjected to different head and neck CT protocols at the studied centres are displayed in figures 1 and 2.

Table 1. Details of physical factors adapted to six computed tomography scan protocols studied in this work

Parameters	Brain (sequential)		Brain (spiral)		Neck -brain (spiral)		Neck (spiral)		Sinus (sequential)		Sinus (spiral)	
Age groups	Paediatric	Adult	Paediatric	Adult	Paediatric	Adult	Paediatric	Adult	Paediatric	Adult	Paediatric	Adult
kVp	139	127	125	146	-	166	120	120	-	113	130	97
mAs	151	223	180	191	-	109	130	156	-	137	225	94
Pitch	1	1	0.87	1.24	-	1.67	1.01	0.8	-	1	0.9	2.63
CTDI (mGy)	24.90	39.46	27.36	38.41	-	16.20	22.35	16.67	-	26.09	44.07	26.67
DLP (mGy.cm)	309.62	497.14	-	755.49	-	1735.16	406.75	198.77	-	142.77	451.71	101.83

CTDI: CT dose index
DLP: dose length product

Table 2. Average dose to the lens of the eye and thyroid from head and neck computed tomography examinations for both age groups

	Number of patients	Thyroid (mGy±SE)	Left eye (mGy±SE)	Right eye (mGy±SE)
Paediatrics (1.5:15 y)	15*	5.89±1.74	15.84±2.81	16.25±2.57
Adults (≥ 15 y)	95*	5.00±1.17	17.64±1.69	24.41±1.89

* On 30 forms, patients’ age was not clearly recorded, thus, they were omitted.

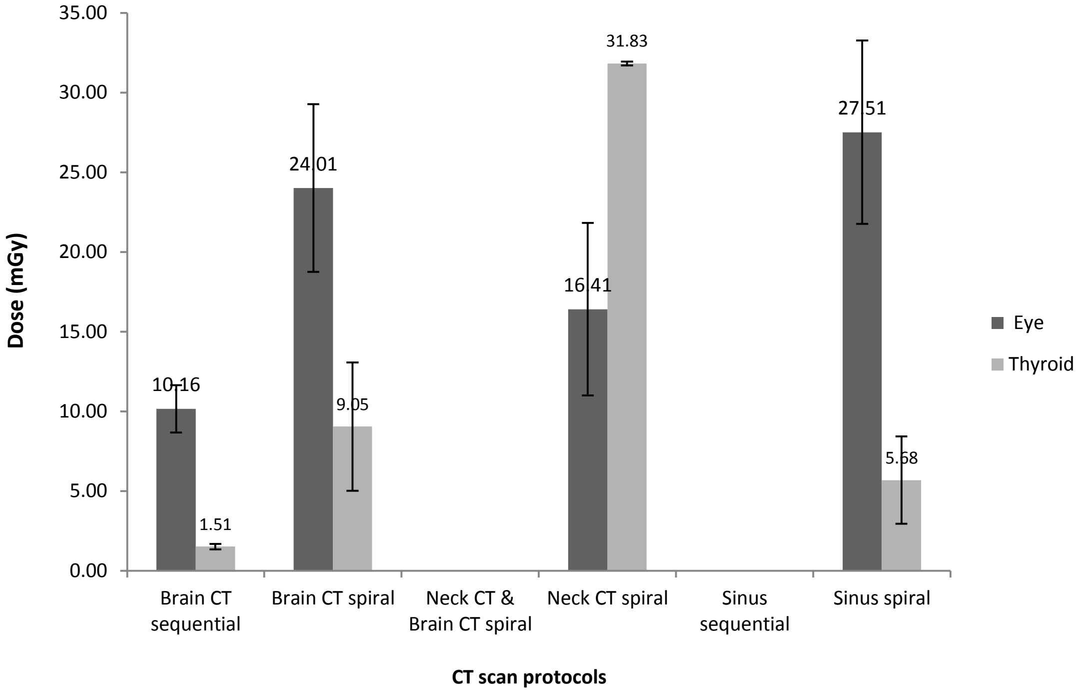

Figure 1. Thyroid and total doses of both eyes of pediatric patients following performing the six computed tomography scan protocols

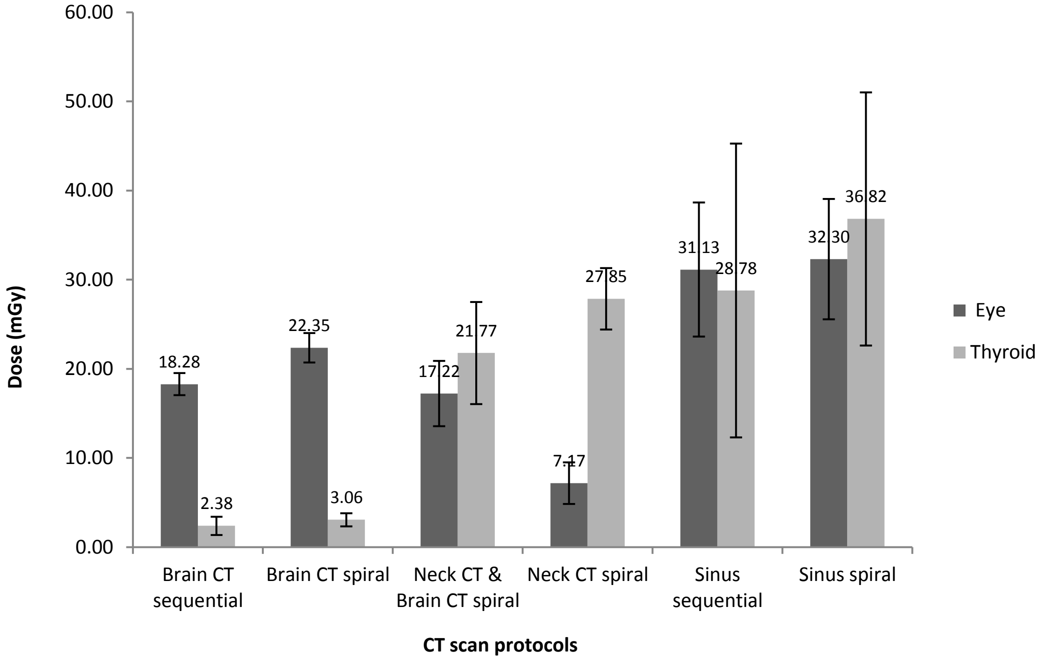

Figure 2. Thyroid and total doses of both eyes of adult patients following performance of the six computed tomography scan protocols

Discussion

In the present study, we estimated the eye and thyroid absorbed doses received by paediatric and adult patients undergone six different head and neck CT protocols. Average doses to the lens of the eye and thyroid from head and neck CT examinations presented in Table 2 indicate that incurred doses to the thyroid and lens of the eye were not very different between the two age groups. The range of lens of the eye dose received by the adult patients was higher than that in the paediatric patients.

Ploussi et al. categorized patients into three age groups and observed that the lens of the eye absorbed dose increased with age [12], which is concerning because paediatric patients have a longer life expectancy after radiation exposure than adults and the lifetime radiation risks are higher for them.

On the other hand, as shown in figures 1 and 2, thyroid dose from brain spiral CT is substantially smaller than the doses delivered to the lenses of both eyes (by a factor of 7 for adults and a factor 2.5 for paediatric patients). On the contrary, thyroid dose from neck spiral CT was higher than the similar values for the lens of both eyes (by a factor of 4 for adults and a factor 2 for paediatric patients) due to the vicinity of the thyroid to the radiation field in neck CT procedures. Radiation exposure to the thyroid gland is a great concern [13], but a threshold for the development of thyroid malignancies is not known, and therefore, any radiation exposure may be hazardous [14].

Figures 1 and 2 show that in the brain and sinus protocols performed in spiral mode, the lens of the eye and thyroid doses are higher than those in the sequential mode. The dose difference between spiral and sequential acquisitions is largely due to the difference in the kVp and mAs used for spiral and sequential protocols.

Table 3. Comparison of organ doses in the current and previous studies

	Dose (mGy)									
Organs	This study	Asgari et al. (2016)	Jibiri et al. (2014)	Suzuki et al. (2010)	Jeff et al. (2010)	Lam et al. (2009)	Tan et al. (2009)	Ngail et al. (2006)	Bassim et al. (2005)	Zammit et al. (2003)
Thyroid	6.92	0.6	*	*	2.8	1.03	*	2.5 (42 Slice)	*	2.2
Eye Lens	19.99 (16 Slice)	20	35.60	50 (54 Slice)	34	12.4 (16 Slice)	18 (16 Slice)	63.9 (42 Slice)	30	30

Table 3 demonstrates the summarized dose data from some other studies compared to our study [3, 11, 15-21]. In our study, the lens of the eye average dose in all the patients was 19.99±18.41 mGy, which is less than the dose recorded in Nigeria by Jibiri et al. (2014) in cranial CT procedures (35.60 ±12.37 mGy). However, the dose obtained in this study was greater than the dose recorded by Asgari et al. (2015) in brain CT (3.27±0.26 mGy) [3, 15]. The variation in the dose could be attributed to the difference in the CT protocols and the number of slices in each study. The usage of contrast could also affect the dose measured.

The dose range reported by Jeff et al. in 2010 for the lens of eye and thyroid were 25.1−50.3 mGy and 0.3−2.8 mGy respectively. Although the dose range we have obtained are not exactly the same, but our result correspond to the lower end of dose range reported by Jeff et al. [16]

Our results revealed that the mean eye dose from different head and neck CT examinations varied from 7.17 mGy to 32.30 mGy depending on protocol type, patient's age and the acquisition mode used. Epidemiological studies of populations who have received low doses of ionizing radiation indicate that lens of the eye is more sensitive than expected, and this may lead us to conclude that cataract may be a stochastic effect (with no threshold) of exposure to ionizing radiation.

Based on these studies and the obtained evidence, ICRP has recently reduced the recommended dose limits for lens of the eye from 2-8 Gy to 0.5 Gy [22]. In the present study, the mean eye dose was much lower than the 500 mGy threshold recommended by ICRP for lens of the eye damage.

Conclusion

The results of this study revealed that in different head and neck CT protocols, the doses received by lens of the eye and thyroid in spiral mode are higher than those in the sequential mode. However, the eye dose in different head and neck CT examinations is much lower than the threshold for lens of the eye damage and it is clinically safe. While CT scan remains a crucial tool, especially for paediatric patients, further dose reduction can be achieved by controlling different factors affecting patient doses. Some of these parameters are user-dependent (e.g., kVp, mAs and pitch). Therefore, optimizing exposure conditions, imaging protocols and patient positioning are necessary for radiation dose reduction, while maintaining sufficient image quality. Radiologists should be trained to reduce exposure ALARA.

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