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Estimation of Radiation Dose to Thyroid Gland for Patients Undergoing Brain Computed Tomography Examinations in Khartoum

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Abstract

As an imaging modality, Computed Tomography (CT) generates greater radiation doses compared to other diagnostic equipment. The requests of CT growth rapidly, accordingly radiation dose assessment and patients' protection are critical. The aim of this study is to assess the radiation dose for patients undergoing brain CT examination in three major hospitals in Khartoum, Sudan. CT Expo software version 2.5 was used to calculate common CT Dose Descriptors: Volume dose index ($CTDI_{vol}$), Dose–Length Product (DLP) and thyroid gland effective dose. The results showed that, the mean $CTDI_{vol}$, DLP and effective dose for all patients in this study were 74.44 mGy, 1431.36 mGy × cm and 4.30 mSv respectively which is lower than that reported by other institutions. It is important to improve imaging technologists' understanding of radiation dose in CT protocols and to obtain regular training with respect to optimization of radiation dose and reduction approach.

Keywords: Computed tomography; Brain; Radiation dose; Thyroid gland; Khartoum

Introduction

Radiation can be divided into two groups: Ionizing and non-ionizing radiation, depending on the harm effect on the exposed tissues. X-rays is a common source of ionizing radiation which is extensively utilized at hospitals and research labs [1]. It is well documented that; a high dose of ionizing radiations can cause human deterministic effects as well as induction of cancer in various tissues [2]. Low radiation doses might potentially rise the risks of biological effects mainly for chronically irradiated or improperly protected workers [3].

Computed Tomography (CT) represents the main source of medical exposure from diagnostic imaging procedures. Despite the fact that CT imaging developed significantly and produce better right diagnosis of many conditions in comparison to other imaging techniques it raises the concern for persons exposed to high dose of radiation during imaging, that depends on age and sex [4-8].

Radiation dose management is needed in order to optimize imaging protocols and for tracking down and avoiding of imaging procedures with high radiation exposure. Two radiation dose indices in CT are used in radiation dose management, namely: The volume CT Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP). $CTDI_{vol}$ is an index of absorbed dose in the scan region and DLP represents an integral of $CTDI_{vol}$ over the longitudinal scan range and shows the overall radiation dose in an imaging series [9,10].

The Diagnostic Reference Levels (DRLs) was first introduced by the International Commission of Radiation Protection (ICRP) in 1996 [11]. DRLs are used to find cases in which radiation dosage is uncommonly, elevated [12]. It is recommended by the International Atomic Energy Agency (IAEA), IRCP and European Commission (EC) that CT examinations should be optimized by comparing of the patient doses with DRLs [12]. Such international organizations motivate individual countries to form their own DRLs as well as carry out regular monitoring for the DRL values. Furthermore, the ICRP recommended that the medical imaging practice to be surveyed by each country to establish its DRLs that will be utilized as indicators, issue guidance for optimization of radiation dose and provide justification of appropriate dose for a particular clinical implication [13,14].

The thyroid gland, which exposed to a serious scatter radiation because of its anatomical location, is considered as one of the most sensitive organs to ionizing radiation, and at highest risk of radiation induced cancer [15,16]. It is reported that medically irradiated patients, the accident of chernobyl reactor, survivors of the atomic bombing and radiation exposure in infancy can induce thyroid malignancy as well as benign thyroid nodules afterwards in life [17,18]. Furthermore, there are autoimmune reactions concerning the thyroid such as thyroid atrophy and hypothyroidism, which may be induced by radiation exposure [19].

In Sudan, the radiation dose for patients undergoing CT examinations was reported by some investigators. Suliman, et al., studied the updates on radiation exposure, and use the results in setting national diagnostic reference levels [20]. They found that the mean $CTDI_{vol}$ ranged: From 63.8 to 16.4 mGy in brain and a Kidney, Ureter and Bladder (KUB); respectively; mean DLP ranged from 1744 to 670 mGy × cm in CT Urography (CTU) and pelvic CT; respectively; while mean effective dose ranged from 21.71 to 1.96 mSv in CTU; respectively. Their results showed wide variations in technique and radiation dose for similar examinations indicating significant room for dose optimisation. Elnour, et al., reported the current CT of the chest–abdomen–pelvis radiation practice in Sudan [21]. They proposed DRLs are $CTDI_{vol}$, 6 mGy and DLP, 970 mGy × cm, and an effective dose of 9.9 mSv. In addition, they found that the organ dose estimation showed that the thyroid received the highest dose during the scan. Naem, et al., investigated new data on patient doses for estimation purposes in CT examinations in Red Sea State [22]. Their study revealed that there are wide variations in patients' doses within and between hospitals for CT.

To the best of our knowledge, there are no studies carried out in the radiation dose to thyroid gland from brain CT in Sudan. In this context, the aim of this study is to estimate the radiation dose to thyroid gland through $CTDI_{vol}$ and DLP as well as effective dose for patients undergoing brain CT examinations in three major hospitals in Khartoum, Sudan. Furthermore, the estimated doses will be compared to the previously published national and international studies.

Materials and Methods

Patients

This study was carried out on 67 patients (39 males and 28 females) who referred to Radiology Department for brain CT in Elzytona, Royal Care and ELmoalem hospitals in Khartoum State, Sudan. Patients without specific radiation dose reports were not included in the study. In addition, verbal informed consent was obtained from all the patients.

CT scanner

Three CT scanners were investigated in this study (one CT machine in each hospital). The specifications of each CT equipment are shown in **Table 1**. The image acquisition parameters according to sex are presented in **Table 2**.

Table 1: CT equipment specifications.

Hospital	Model	Number of slices
Elzytona	TOSHIBA scanner aquilion (model TSX-101A, the input 200 V 50/60 HZ, Max input power 100 KVA).	64
Royal care	TOSHIBA scanner aquilion (model TSX-101A, the input 200 V 50/60 HZ, Max input power 100 KVA).	64
ELmoalem	TOSHIBA scanner prime (model CXXG-012A), the input 200 V 50/60 HZ, Max input power 90 KVA).	160

Table 2: Image acquisition parameters according to sex.

Gender	Age	Tube voltage (KVp)	Tube current (mA)	Pitch	Slice thickness (mm)	Number of slices	Slice length (cm)
Male	47.3 ± 20.2	120	197.6 ± 42.11	0.98	5	650 ± 32	15 ± 2.17
Female	51.9 ± 20.9	120	217 ± 23.1	0.96	5	622±76.04	14.98 ± 2.01

Dose estimation

CT-Expo V 2.3 is an MS excel application written in visual basic for the calculation of patient dose in CT examinations. It allows the calculation of the following dose quantities; weighted CTDI, volume CTDI (effective CTDI), Dose-Length Product (DLP), organ doses, effective dose (according to ICRP 60 and 103). In contrast to similar programs for dose calculations in CT, CT-Expo V 2.3 offers the user a number of unique features, such as; dose calculations for all age groups (adults, children, neonates), dose calculations for each gender and dose calculations for all existing scanner models [23].

Data analysis

OriginPro 8 was used to perform statistical analysis. Categorical data is represented as frequencies with percentages. Mean ± Standard Deviation (SD) or median (Interquartile Range, IQR) was used for continuous data depending on normality.

Results and Discussion

The radiology community is becoming increasingly worried about the radiation dose resultant from the CT as its broad use has given rise to the radiation dose of the patients and consequently an increase in the prevalence of cancer mainly in thyroid as it is a sensitive organ to radiation [24].

It was reported that, $CTDI_{vol}$ represents a very practical way to correlate the doses delivered by different scan protocols or to attain a particular level of image quality for a particular patient size. In addition, with use of technique charts and diagnostic reference levels, $CTDI_{vol}$ can be utilized to set down the right dose for a particular patient size and diagnostic task [25]. **Table 3** shows $CTDI_{vol}$ and DLP for all patients (males and females) in the studied hospitals. The mean values for the $CTDI_{vol}$ were 81.88, 76.96 and 61.88 mGy for Elzaytona, Royal Care and Elmoalem hospitals respectively and the highest value shown in Elzaytona hospital. Furthermore, the mean values for the DLP were 1721.15, 1369.71 and 1101.80 mGy × cm for Elzaytona, Royal Care and Elmoalem hospital respectively. From **Table 3** it can be observed that Elzaytona hospital showed the highest DLP value. It was reported that, the elevated radiation dose for patients in CT depends on several factors such as, inappropriate exposure parameters, duplicated examinations, overlapped scans, and likely larger scan volume coverage [25].

Table 3: $CTDI_{vol}$ and DLP for all patients in hospitals.

Hospital	$CTDI_{vol}$ (mGy) (Min–Max) Mean ± SD	DLP(mGy × cm) Mean ± SD (Min–Max)
Elzaytona	81.88 ± 5.94 (77.3-95.4)	1721.15 ± 241.62 (1283.4-2190.6)
Royal care	76.96 ± 10.33 (48.0-95.4)	1369.71 ± 238.92 (772.8-1826.9)
Elmoalem	61.88 ± 2.03 (59.50-65.40)	1101.80 ± 289.64 (848.2-1394.9)
All patients	74.44 ± 10.87 (48.00-95.40)	1431.36 ± 363.32 (772.8-2190.6)

The $CTDI_{vol}$ and DLP were also classified according to sex in hospitals as shown in **Table 4**. The females showed higher mean $CTDI_{vol}$ (76.12) and DLP (1369.71) indices compared to the males. These comparisons are further illustrated by **Figures 1 and 2**.

Table 4: $CTDI_{vol}$ and DLP for males and females in all hospitals.

Gender	$CTDI_{vol}$ (mGy) Mean ± SD (Min-Max)	DLP(mGy × cm) Mean ± SD (Min-Max)
Male	70.5 ± 11.34 (48-80.8)	1327.28 ± 254.23 (772.8-1826.9)
Female	76.12 ± 10.33 (59.5-95.4)	1369.71 ± 238.92 (772.8-1826.9)

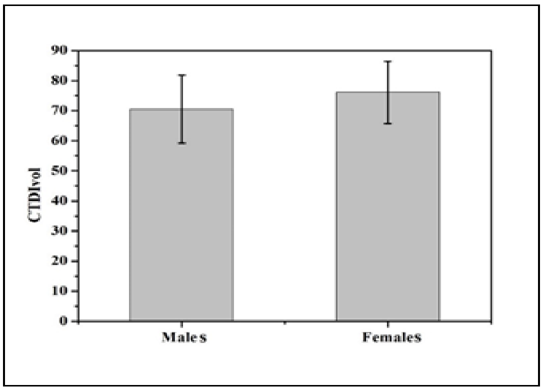

Figure 1: Comparison of $CTDI_{vol}$ among males and females in all hospitals.

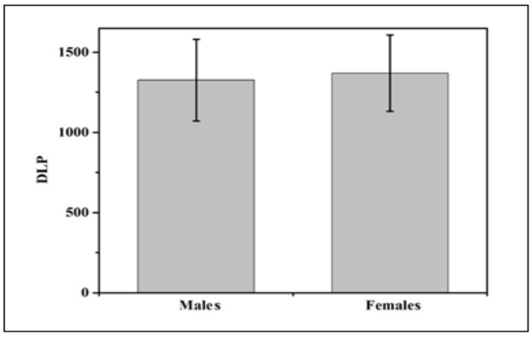

Figure 2: Comparison of DLP among males and females in all hospitals.

Effective dose was originally evolved by the (ICRP) as a risk-adjusted dosimetric quantity in order to the manage the protection against stochastic effects, mainly cancer, facilitating comparison of intended or received doses with dose constraints, dose limits and reference levels indicated in the same quantity [26].

The effective doses of the thyroid for all patients in the three hospitals are shown in **Table 5**. The highest and lowest effective dose values were 5.60 and 3.30 mSv in Elzaytona and Elmoalem hospitals respectively. **Figure 3** represents a comparison of the effective dose among the studied hospitals. Furthermore, the effective dose values were also classified according to the sex. There are no differences for the effective doses among both males (3.50 mSv) and females (3.53 mSv) as we can notice in **Table 6**. These values are less than that reported by Hiba *et al.,* as they found that the mean effective dose for patients undergoing brain CT examinations in Khartoum is 5.48 and 5.99 mSv for males and females respectively [27]. It was further reported that head CT scanning is commonly related, with high doses of radiation with the effective dose spanned from 1.2 to 8.8 mSv for procedure [28].

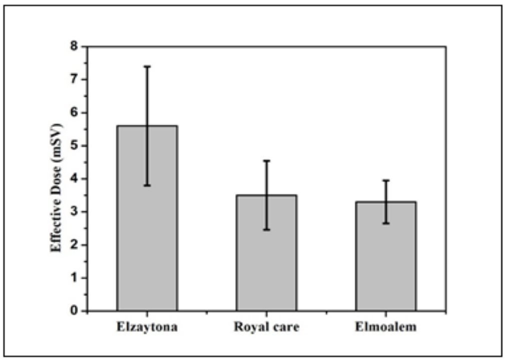

Figure 3: Comparison of thyroid effective dose for patients in all hospitals.

Table 5: Effective dose (mSv) of thyroid for all patients in hospitals.

Hospital	Mean ± SD	(Min-Max)
Elzaytona	(5.60 ± 1.80)	(2.9-9.4)
Royal care	(3.59 ± 1.04)	(1.5-6.2)
Elmoalem	(3.30 ± 0.65)	(1.8-4.60)
All patients	(4.30 ± 1.70)	(1.50-9.40)

Table 6: Effective dose (mSv) of thyroid for males and females' patients in all hospitals.

Gender	Mean ± SD	(Min-Max)
Males	3.50 ± 1.02	1.50-6.20
Females	3.53 ± 1.04	1.50-6.20

We have compared the $CTDI_{vol}$ and DLP that we estimate in this study with other national and international published works from Sudan, Ethiopia, Morocco, Nigeria, Egypt, Iraq, Japan, Northern Ireland and Taiwan **(Table 7)**.

Table 7 comparison of mean $CTDI_{vol}$ and DLP obtained in the present study with previously published papers for CT brain scan examinations.

Study	**$CTDI_{vol}$ (mGy)**	**DLP (mGy × cm)**
Present study	74.44	1431.36
Sudan 2016 [20]	63.8	1744
Ethiopia 2023 [29]	43.27	988.52
Morocco 2021 [30]	57.4	1020
Nigeria 2018 [31]	61	1310
Egypt 2017 [32]	30	1360
Iraq 2016 [33]	84.68	1642.76
Japan 2015 [34]	85	1350
Northern Ireland 2004 [35]	60	1050
Taiwan 2010 [35]	72	850

From **Table 7** we can observe that the lowest and highest mean $CTDI_{vol}$ were reported by Egypt (30 mGy) and Japan (85 mGy) respectively. Whereas the lowest and highest DLP were reported by Taiwan (850 mGy × cm) and Iraq (1642.76 mGy × cm) respectively. In addition, it can be noticed that, there is large variation in the $CTDI_{vol}$ and DLP values among these international institutions. There are many possible reasons why CT doses differ among hospitals. It is reported that different CT techniques are the primary. Furthermore, patients' doses can be reduced by increasing pitch factor and reducing kVp and tube current [36,37]. In addition, imaging technologists training and attentions of CT scan technical aspects have substantial contribution in patient dose [38]. The imaging protocols used by the imaging technologists in different countries vary, and such variations are reliant on the experience and training of the operators.

Conclusion

We conclude that, the mean $CTDI_{vol}$, DLP and effective dose for all patients in this study were 74.44 mGy, 1431.36 mGy × cm and 4.30 mSv respectively and found lower than that reported by other institutions. With convenient assessment of patient radiation dose, radiation awareness will be improved.

The exposure to ionizing radiation should be reduced and kept as low as reasonably achievable. CT imaging procedure depends on the operator; hence continuous training in CT operation and radiation safety is necessary.

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