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Original article

Radiation Dose and Cancer Risk for Patient Undergoing Computed Tomography for Selected Organs in Omdurman Locality

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Abstract

This study intends to measure the patient radiation dose during computed tomography examination absorbed in Brain and Pelvic. The data was collected in regard to exposure parameter in CT procedures performed for 189 adult patients undergoing Pelvic and Brain scan from two hospitals in Omdurman locality. The obtained results indicated that the effective dose in hospital (A) for Brain was (3.39±0.65) (mSv) and for Pelvic was (52.86±33.57) (mSv), and the effective dose in hospital (B) was (3.54±1.02) mSv for Brain, and (29.01±14.17) mSv for Pelvic. Patient dose received in hospital (A) was higher in Pelvic examination than in the other hospital. This result could be due to increasing number of photons and number of slices. The patient's doses in two hospitals were higher than the doses in previous studies. The overall patient risk per CT procedure ranges between 19.09 and 223.8. This finding can be attributed to the fact that radiosensitive organs are exposed to the primary beam, hence the effective dose is higher compared to cerebral and extremity CT. The radiation induced cancer for females are obviously higher than those for males, while for procedures that incorporate the pelvic region, radiation risks in males were slightly higher than those in females. Considering only the average values of effective doses found in this study, it is obviously that value for the brain and pelvic are higher than the average values reported in the literature. Whereas average value of head and pelvic exams are greater by 75% and >250% respectively compared to data in literature, even though the CTDI values for head and pelvic scan are much higher. Patients are exposed to high radiation doses.

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INTRODUCTION

In the last decades much technological advancement had been occurred in medical field. The development of Computed Tomography scanners has been one of the most explosive phenomena in modern medicine. (Maher and Malone1997).

The CT principles were introduced by Sir Godfrey Hounsfield and Alla Cormack in 1972. The fundamental principle of CT is that the two-dimensional structure of an object, can be reconstructed from a number of one-dimensional 'projections' acquired at different angles, followed by appropriate image reconstruction, solid-state

detectors is situated opposite the X-ray tube and they record together a one-dimensional projection of the patient.
(Smith and Webb 2011)

Computed tomography (CT), is an X-ray imaging technique that produced high quality cross-sectional images of the body and it is responsible for generating higher doses to patients compared to other diagnostic imaging modalities.

Absorbed Dose

Absorbed dose is a non-stochastic quantity relevant to all types of ionizing radiation fields. It is defining as a dose of 100 ergs of energy per gram of the certain material. The international unit for absorbed dose is the gray (Gy), which is defined as a dose of one joule per kilogram. The absorbed dose can be calculated by using the following formula

$$D = \frac{E}{m} \quad (2) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where D is the absorbed dose, E is the energy, m is the mass of the absorbing material.(Podgorsak, 2005).

2.7.2 Effective Dose

The effective dose, *E*, is a measure of the combined detriment from stochastic effects for all organs and tissues for an average adult. It is the sum over all the organs and tissues of the body of the product of the equivalent dose, *H*T, to the tissue or organ and a tissue weighting factor, *w*T , for that organ or tissue

$$E=WT.HT\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The tissue weighting factor, WT, for organ or tissue T represents the relative contribution of that organ or tissue to the total 'detriment' arising from stochastic effects for uniform irradiation of the whole body. The sum over all the organs and tissues of the body of the tissue weighting factors, WT, is unity. The international unit for effective dose is the Sievert (Sv).

Equivalent Dose

Different types of ionizing radiation can cause stochastic effects of different magnitudes for the same value of the absorbed dose. The equivalent dose, HT, to an organ or tissue, T, is used. For a single type of radiation, R, it is the product of organ dose, D_T, for radiation R and a radiation weighting factor, W_R.

$$H_T = W_R . D_T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The radiation weighting factor, W_R, describe the relative biological effectiveness of the incurred radiation in producing stochastic effects as a result of low radiation doses in organ or tissue T. In diagnostic radiology procedures, W_R is generally taken to be unity. The SI unit for equivalent dose is the Sievert (Sv)

CT Dose Measurement

Computed Tomography Dose Index Volume (CTDIvol)

Computed Tomography Dose Index Volume (CTDIvol) used to represent dose for a specific scan protocol, which usually involves a series of scans, it is essential to take into account any overlaps or gaps between the x-ray beams from consecutive rotations of the x-ray source (Shettima, *et al* 2017)

Dose-Length Product (DLP)

To real represent the overall energy delivered by a given scan the protocol, absorbed dose can be integrated along the scan length to compute the Dose-Length Product (DLP) (Shultis., *et al* 1996).

Computed Tomography Scans and Radiation Risk

In all medical applications there are both benefits and risks associated with the use of radiation. The main risks are associated with the increased possibility on cancer caused by x-ray exposure because it can give high radiation exposure.

The probability for absorbed x rays to induce cancer or inheritable mutations leading to genetically associated diseases in offspring is thought to be very small for radiation doses of the magnitude that are associated with CT scan procedure .(Itoh et *al.*, 2001). CT is increasingly strong evidence that exposures to radiation levels found during CT scans may increase the risk of future cancer (Shrimpton *et al*,. 2006 and Itoh et *al*,. 2001).)

OBJECTIVES

The aim of this work is to investigate the radiation doses imparted to patients during pelvic and brain CT examinations and estimate the cancer risk associated with delivered radiation exposure.

MATERIALS AND METHODS

Data of this study were collected from two hospitals in Omdurman region. Both devices in this study are Toshiba (Aquilion) had 64 slices; they are classified in the following table

Table (1): The device information for A and B hospitals.

Part	Data	Machine A	Machine B
Gantry	SN	1AC1164845	1AA06Y2452
	Modal	CGGT-021A	CGGT-021A
	Max input power	25KVA	25KVA
scanner	SN	HCB1163908	HCA06Y2400
	Modal	TSX-101A	TSX- 101A
	Max input power	100KVA	100KVA
X-Ray High Voltage Generator	Modal	CXXG-012A	CXXG-012A
	Max input power	90KVA	90KVA
	Output power	120KV,600mA 135KV, 530mA	120KV,600mA 135KV, 530mA

Patient Data

189 different adult patients for Pelvic and Brain scan from different hospitals are collected in four months.

Method

Effective Doses Estimations

DLP (mGy.cm) was used to estimate the organ-effective dose (E) for brain and pelvic region using the following equation.

$$E = DLP * k \quad (4)$$

Where E = Effective Dose in mSv , DLP = Dose Length Product in mGy*cm,

k = conversion coefficient in mSv/mGy*cm, k is known (e.g. 0.0021 for adult head,0 .015 for abdomen, etc. (ICRP report 103)

Cancer risk estimation

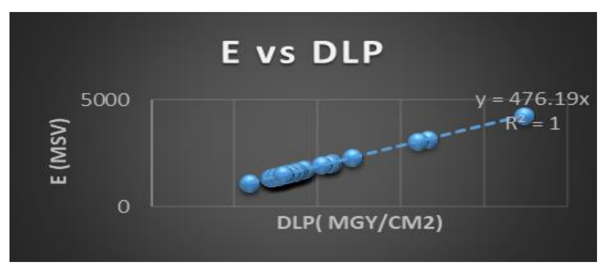
The overall cancer risk per procedure was obtained by multiplying effective dose with the risk coefficients (fT) (5.5 Sv^{-1}) (ICRP, 2007)

RESULTS AND DISCUSSION

In this study, a total of 189 patients were examined in two hospitals in Omdurman over six months. The obtained results were tabulated and figured here. Table 1 shows patient number during brain and pelvic CT scan of 93 patients for brain and 96 patients for Pelvic examinations. Table (2) and table (3) shows patient exposure parameters during CT scan according to gender in brain and pelvic respectively. Whereas in table (4) represent Patients' doses during brain and pelvic CT procedures .in table (5) Overall cancer risk per procedure are determined. Then comparison of effective dose (mSv) values between this study and literature are presented in table (6).

Table (2): Patient data distribution according to gender for brain and pelvic CT examination procedures.

Hospitals	Gender	Brain	Pelvic
A	Male	27	18
	female	19	29
	Total	46	47
B	Male	29	27
	female	18	22
	Total	47	49



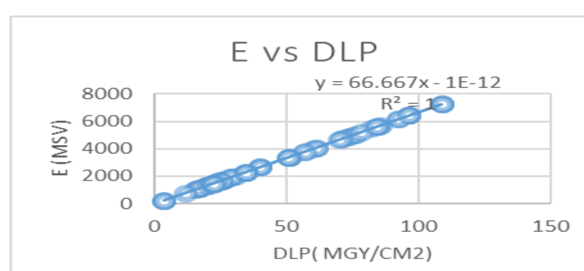


Figure (1): Relation between effective dose (mSv) and dose length product (mGy/cm^2) (a) for Brain (b) for Pelvic

Table (3): Image acquisition in gender in brain examination.

Center	Gender	Age (year)	Total time (s)	Tube current (mA)	Scanlength(mm)	Total no of slice
A	Male	49.3±20.9 (17-85)	15:45 (23:38-4:35)	4339.8±415.0 (5589-3226)	182.7±17.26 (205.6-17.26)	531.7±110.48 (1016-353)
	female	60.52±17.52 (83-18)	10:44 (23:40-0:50)	4416.8±1130.5 (6226-3735)	177.6±27.17 (278.8-154.8)	533.3±151.9 (1030-420)
B	Male	50.0±19.9 (85-18)	14:26 (21:37-2:13)	4628±1175.1 (9716-3226)	184.9±34.12 (318-143.2)	574.5±189 (1326-353)
	female	61.7±18.5 (95-33)	14:54 (23:40-0:50)	4243±586.4 (6226-3735)	180.3±28.9 (278.8-154.8)	510.2±93.7 (839-420)

Tube voltage= 120 kv slice thickness=5 mm

Table (4): Image acquisition in gender in Pelvic examination.

Center	Gender	Age (year)	Total time (s)	Tube current (mA)	Scan length (mm)	Total no of slice
A	Male	55.4±23.4 (88-21)	10:11 (14:29-8:13)	7986±6849.4 (18362-769)	407.2±141.2 (545.6-167)	2058.7±1372.1 (4994-350)
	female	55.2±15.2 (80-22)	10:08 (14:29-0:57)	9712.9±4661.8 (16227-2843)	477±58.1 (644-420)	2303±922.2 (4994-569)
B	Male	52.6±21.7 (94-18)	827:3 (15.39-0:55)	5821±3763.6 (20085-3684)	239.2±112.6 (500-174)	1033.5±1096.6 (4255-464)
	female	62.3±19.7 (94-18)	12:0 (23:40-0:50)	4770.6±1326.2 (6226-2090)	242.8±104.8 (464.4-164)	830.6±….. (2694-420)

Tube voltage= 120 kv slice thickness=7mm

Table (5): Patients' doses during brain and pelvic CT procedures.

Center	Procedure	CTDIvol (mGy)	DLP (mGy_cm)	Effective dose (mSv)
	pelvic	81.8±51.2 (214.6-9.4)	3524±2237.9 (7248-231.2)	52.86±33.57
B	brain	79.7±18.6 (150.8-72.2)	1687±487.7 (4269-1125.7)	3.54±1.02
	pelvic	75.6±16.8 (138.2-72.2)	1935±945.3 (5227.2-1338.4	29.01±14.17

Table (6): Overall cancer risk per procedure.

CT procedure	Mean effective dose(mSv)	Risk coefficient (S v–1)	Cancer Probability 10^{-5}
Brain	3.47	5.5×10^{-2}	19.09
Pelvic	40.69		223.80

Table (7): The present results compared with evaluable literature (mSv)

study	brain	pelvic
This study	3.47	40.9
NRPB- standards. [32]	(1.78)	(10.0)
RCR- standards. [33]	(2.0)	(11.21)
Wade et al. [30]	(1.0)	(6.0)
Clark et al. [31]	(1.9)	(8.4)

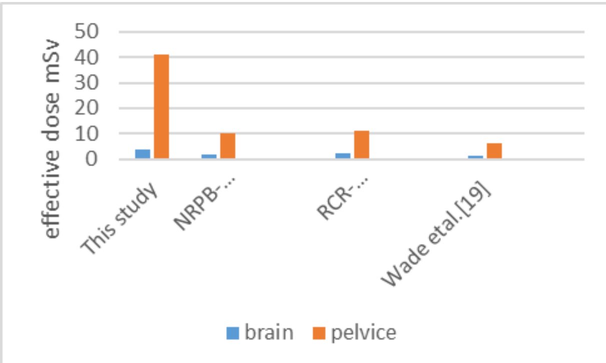


Figure (2): Effective dose during CT for Brain and Pelvic in previous studies

DISCUSION

In this study, a total of 189 patients were examined in two Hospitals in Omdurman over 4 months. Table (2) shows patient number detail during brain and pelvic CT scan. CT examinations in adult patients have contributed greatly to the diagnosis of different diseases; however, the radiation exposure to the patient is significantly higher compared with other radiologic examinations. Table (3) and table (4) represents the scan parameter per procedure. A constant voltage potential (120 kVp) was used for CT procedures with variable mAs, which ranged from 769 to 20085 mAs. This variation in mAs could be attributed to different patient size and also differed based on the different type of CT examination (i.e., Brain, and pelvis). In addition, variation between DLP values may have resulted from differences in mAs and time for all CT examinations. In general, the patient radiation dose is proportional to tube current–time product (mAs). Therefore, reduction of the tube current will also decrease the radiation dose by the same value. In an ideal situation, image acquisition parameters were adjusted according to scanned anatomy. Table (4) shows the mean and range of values of CTDIvol (mGy), DLP (mGy_cm) and effective dose (mSv) per procedure. Effective dose, which is gender-averaged and risk-adjusted dosimetric quantity, allows the estimation of nominal risk coefficients for uniform external radiation exposure. It also allows the comparison with patient doses in other imaging modalities and reference levels. The highest radiation dose and the highest effective dose in pelvic CT.The results obtained in this study are higher in the ranges reported in previous study. There are many factors that affect the radiation dose from CT. These factors include beam energy, tube current, rotation or exposure time, slice thickness, pitch, and dose reduction techniques, such as the tube current modulation technique. It has been reported that the effective dose from CT procedures can often approach or exceed levels known to increase the probability of cancer (Brenner 2001). The overall patient risk per CT procedure ranges between 19.09 and 223.8 (Table 6). The highest cancer risk for patients occurs during pelvic (Table 6). This finding can be attributed to the fact that radiosensitive organs are exposed to the primary beam, hence the effective dose is higher compared to cerebral and extremity CT. Huda, 2012 reported that, the radiation induced cancer for females are obviously higher than those for males, while for procedures that incorporate the pelvic region, radiation risks in males were slightly higher than those in females. The risks for male and females were similar for CT abdomen (Huda et al 2000).

Considering only the average values of effective doses found in this study, it is obviously that values for the brain and pelvic are higher than the average values reported in the literature.

Whereas average value of head and pelvic exams are greater by 75% and >250% respectively comparable to data in literature, even though the CTDI values for head and pelvic scan are much higher.

Actually, the effective dose value is a reflection of the overall factors that determine the radiation exposure produced by the machine. Those factors are including physical factors selected for each exam, such as the KV, mAs, slice thickness and number of slices. It was observed in this study that in general the effective dose values are correlated to the corresponding dose length product (DLP) values, i.e. low DLP values leads to low effective dose values as shown in figure (1).

CONCLUSION AND RECOMMENDATIONS

- Patients are exposed to high radiation doses. Estimation of patient radiation risk helps to improve staff awareness of radiation exposure consequences from medical procedures to keep the patient radiation dose as low as reasonably achievable.
- Radiosensitive organs receive a significant radiation dose during CT procedures, therefore rigorous reassessment of justification criteria and optimization measures of the procedure are needed.
- Special concern is recommended in justifying CTA procedures for young female patients. Comprehensible justification of examinations is highly recommended, and repetition of examinations should be avoided.
- Operators they generated CT scanners should have enough experience to protect patients.
- Continuous calibration and preventive maintenance is needed for these equipment's.
- Quality control of CT machine should be done to verify the factors that affect patient dose and image quality.

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