ORIGINAL ARTICLE

EFFECTIVE DOSES ASSOCIATED WITH CT EXAMINATIONS AND RADIATION INDUCED LIFETIME CANCER RISK ESTIMATION

Iqra Tanveer,[1] S.U. Rahman,[2] Ghulam Asghar,[1] Muhammad Munir,[3] Humera Mehmood,[2] Mohammad Faheem[2]

[1] Department of Physics, University of Poonch, Rawalakot, AJK, Pakistan
[2] Atomic Energy Cancer Hospital, AECH-NORI, Islamabad, Pakistan
[3] Radiation Dosimetry Lab, HPD, PINSTECH, Nilore, Islamabad, Pakistan

PJR October - December 2017; 27(4): 353-357

ABSTRACT

BACKGROUND: Computed Tomography (CT) examinations are increased significantly over the past three decades. However CT contributed substantially higher radiation doses as compared to conventional x-ray procedures. In this study, the radiation doses are estimated for head and chest CT procedures and calculated the cancer risks on the basis of measured doses. **MATERIAL AND METHODS:** CT doses are estimated by using scanner derived parameters and thermo luminescent dosimeters (TLD) for head and chest CT procedure. TLD chips were placed on the exposed area of the selected patients and one TLD for each patient placed outside the field to measure the scattered radiation. Age, weight and height of all selected patients were recorded. To evaluate the TLD dose, exposed TLDs were read with TLD reader. **RESULTS:** Mean doses of male and female patient for head CT procedure measured with CT generated dose index and TLD were 57.59 ± 2.354 mGy and 47.1 ± 5.35 mGy respectively. Mean doses for chest scan generated with CT dose index was 8.82 ± 2.09 mGy and measured with TLD came out to be 15.73 ± 5.2 mGy. The mean effective doses calculated for CT and TLD were 2.0 ± 0.579 mSv and 0.443 ± 0.043 mSv during head CT procedure and 5.6 ± 0.913 mSv and 1.7 ± 0.754 mSv found for chest CT examination. Based on measured data lifetime excess cancer risks for head and chest CT were calculated. **CONCLUSION:** Radiation doses measured from selected procedures in diagnostic CT examinations were lower than the recommended dose limits and variable within the same examinations. The calculated doses from CT derived parameters and TLD do not exceed the recommended safe limits for head and chest CT procedures.

Key words: Thermo luminescent dosimeter, effective dose, computed tomography, cancer risk, radiation dose

Introduction

The use of CT improved health care of patients and it is considered the most important tool in diagnostic studies. CT is associated with substantially higher radiation doses as compared to conventional x-rays examinations.[1,2] Hence, greater utilization of CT in diagnostic procedures eventually increases medical exposures to ionizing radiation. It is estimated that radiation from medical procedure is the largest source of exposure to people living over the globe.[3-5] Ionizing radiation exposures at all levels are considered harmful for human being. Exposures from diagnostic medical studies and related health risks of ionizing radiation are reported in BEIR-VII. The higher exposure per CT examination may cause cancer risk. However, the risk to an individual patient may be small but increasing CT examinations and number of individuals exposed to ionizing radiation may cause increase of cancer risks. CT delivers much higher

Correspondence : Dr. Saeed ur Rahman
Atomic Energy Cancer Hospital,
AECH-NORI,
Islamabad, Pakistan
Email: snori66@gmail.com

Submitted 19 August 2017, Accepted 25 August 2017

radiation doses than conventional diagnostic x-rays, which may increase a person's lifetime risk of developing cancer.[6,7]

The extensive use of CT and other diagnostic procedures using ionizing radiation has raised concern that even small increases in cancer risk could lead to large numbers of future cancers.[8] It is important to understand and quantify the radiation dose in CT imaging so the potential for harm could be balanced against the potential for benefit.[9] When clinically justified, CT exams benefits are outweigh its associated risks, and even it is advisable to use the minimum level of radiation dose to achieve the required results.

The radiation doses to particular organs for any given CT study depend on a number of factors. The most important are the number of scans, the tube current and scanning time, size of the patient, the axial scan range, the scan pitch, tube voltage and the specific design of the scanner being used. Many of these factors are under the control of the technologist. Ideally, they should be tailored to the type of study being performed and to the size of the particular patient.

CT is one of the most important radiological examinations worldwide and may be considered as an efficient tool for diagnosing illness. To date, relatively few data describe how much radiation is received through the most common types of CT examinations when applied in clinical practice. This study aimed to estimate how much radiation exposure is associated with the types of CT examinations performed commonly. The lifetime attributable risk of cancer associated with performed tests estimated on the basis of measured data. This study would help to estimate the radiation dose associated with common CT examinations in clinical practice and quantify the cancer risk associated with these studies.

Material and Method

Present study is conducted at Nuclear Medicine Oncology and Radiotherapy Institute (NORI), Islamabad. In this study total 22 patients including children, female and male were randomly selected undergoing CT procedure of chest and head. Siemen's SOMATOM Sensation Open CT scanner is installed at NORI with four standard X-rays energies (80kV, 100kV, 120kV and 140kV).

CT dose measurement

CT doses are calculated to consider patient individual exposure parameter. The parameters include, tube voltage (kV), tube current and exposure time (mAs), CT dose descriptor CTDI, scan time, pitch and slice thickness. CT doses were calculated based on these technical parameter of each exposure and measured output. The CT doses are highly dependent on the scan parameters.

Effective dose is found using the dose length product (DLP), which is recorded as a major aspect of CT exam. Effective dose is calculated using the following relation

$$\text{Effective dose} = \text{DLP} \times k$$

Where "k" is the conversion factor to account for the sensitivities of various organs to increasing radiation induced cancer. The factors for different organs are given in the literature.[5,8,9]

The DLP given in the above equation is calculated by using the relation.

$$\text{DLP} = \text{CTDIvol} \times \text{Scan length}$$

TLD dose measurement

In order to measure the organ dose, TLD chip were placed on the scan area to measure the absorbed dose for each patient during the CT examination for head and chest procedures. Beside the scanned area, one TLD is placed outside the exposed field. The organs outside the field selected are eye in case of chest CT examination and chest in case of head CT procedure to measured the doses outside the exposed field. The exposed TLDs were read in the Radiation Dosimetry Lab. The TLD reader is installed in the Radiation Dosimetry Lab, PINSTECH, Islamabad. Dose measured with TLD converted into equivalent dose by multiplying it with radiation weighting factor that is 1 for X - rays.

$$\text{Equivalent dose} = \text{absorbed dose} \times W_R$$

Equivalent dose converted into effective dose by multiplying it with tissue weighting factor for head and chest published in literature ICRP 2007.

$$\text{Effective dose} = \text{Equivalent dose} \times W_T$$

Results and Discussion

In this study, 22 patients for head and chest examinations were randomly selected. The radiation doses are measured for head and chest CT procedures and corresponding radiation-induced cancer risks are calculated on the basis of measured doses.

Doses for head scan

CT generated effective doses for selected patients having head examination in the present study are given in (Fig. 1). Effective dose for each patient undergoing CT procedure for head scan measured with TLD is shown in (Fig. 2). In both cases the mean measured doses are less than the recommended mean effective dose limits for head CT which is 2.0 mSv.[5,9,10] However, it is clear from (Fig. 1), the patients 1 and 2 have very low doses, because these two patients are small children and pediatrics parameters were selected. The mean effective dose for two selected children was not included in the study.

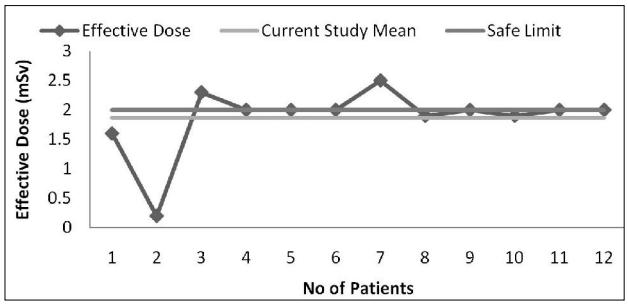

Figure 1: Effective doses measured from CT generated for head CT procedure.

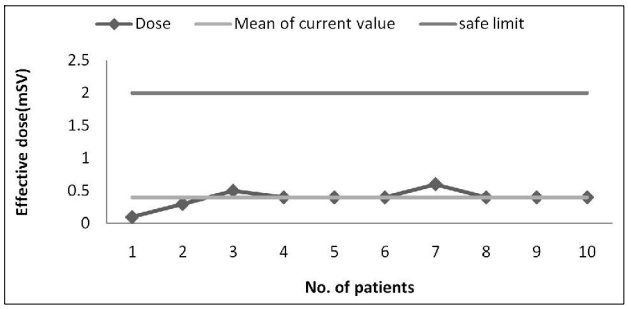

Figure 2: Effective doses measured with TLD for head CT procedure

Overall mean patient doses for head CT measured with CT generated dose index and TLD for male and female patient are 57.59 ± 2.354 mGy and 47.1 ± 5.35 mGy respectively. Mean effective dose calculated for head CT generated from CT dose index and with TLD found to be 2.093 ± 0.579 mSv and 0.460 ± 0.043 mSv. Overall Mean measured and calculated effective doses for head CT are shown in (Tab. 1).

Measured CT generated dose (mGy)	Measured TLD dose (mGy)	Calculated effective doses for CT generated (mSv)	Calculated effective doses for TLD (mSv)
57.59 ± 2.354	47.14 ± 5.355	2.093 ± 0.579	0.460 ± 0.043

Table 1: Overall mean measured doses and calculated effective doses generated by CT and TLD for head scan

Mean height, weight, age, sex related to selected patients for head CT examinations and different parameter related to CT are shown in (Tab. 2). It is clear from the (Tab. 2), mean doses for children, male and female in CT generated are 32.59, 57.93 and 57.26 mGy respectively. The mean measured doses from TLD for children, male and female are 22.6, 48.40 and 47.89 mSv respectively. The children selected for this study are very small number due to time limitation of the research project.

Sex	Mean Age(y)	Mean Height (cm)	mAs	CTDI (mGy)	Dose (mGy)	Scan time(s)	Pitch	Slice (mm)
Child	3.5	36.75	88.5	32.59	22.6	14.16	0.5	5
Male	33	161	246	57.93	48.40	15.46	0.5	5
Female	43	150	157	57.26	47.89	12.59	0.55	5

Table 2: Mean values of different parameter related to CT and patients selected for head CT procedure

Dose length product (DLP), calculated effective doses due to CT scanner and TLDs are shown in (Tab. 3). Scattered doses were also measured with TLDs and also shown in (Tab. 3). CT Doses outside the exposed field (chest in case of head CT procedures) were measured using TLDs and varies from 0.50 to 0.54 mGy. Effective doses for CTDI ranged from 0.9 to 2.0 mSv for children and female. Effective doses calculated for TLDs are 0.2 mSv for children and 0.4 mSv for both males and females.

Sex	DLP (mGycm)	Dose on the chest due to head CT (mGy)	Effective doses of CTDI (mSv)	Effective dose of TLDs (mSv)
Child	426.5	0.54	0.9	0.2
Male	1115.1	0.50	1.8	0.47
Female	954.9	0.52	2.0	0.4

Table 3: DLP, effective dose and TLD dose for head CT

Estimation of cancer risk for head CT procedure

To evaluate the cancer risk, average age and average dose is calculated separately for children, male and female patients. The average age for children is 3.5 yr (2-5 yr) and average effective dose calculated for CT and TLD is 0.9 and 0.2 mSv for head CT procedure. The cancer risks calculated based on measured doses for children in case of CT and TLD are 1 in 2802 and 1 in 11908 persons.[7,11-13] The average age of selected male patients was 33 yr (17-55 yr), and mean effective dose for CT and TLD found to be 2.13 and 0.474 mSv. The average age for female patients was 43 yr (20-50yr) and average dose for CT and TLDs came out to be 2.0 and 0.4 mSv. The calculated cancer risks for male from the doses of CT and TLD found to be 1 in 1549 and 1 in 5228 and for female patient from CT and TLD dose found to be 1 in 1158 and 1 in 5831 respectively.

Doses for chest scan

Effective doses for chest CT generated with CT scanner for selected patients are shown (Fig. 3). CT doses measured with TLD for chest examination and corresponding effective doses are shown in (Fig. 4). It is obvious from (Fig. 3 and 4) that effective doses varied significantly for chest CT procedures. The doses for all patients selected for chest CT examinations measured with TLD are less than recommended safe limits (7.0 mSv).[5,9,10] However, the dose of a single patient greater than the safe limit in CT generated doses as shown in (Fig. 3). It is found that this particular patient has more scan area as compared to the others and it was recommended by the referring physician.

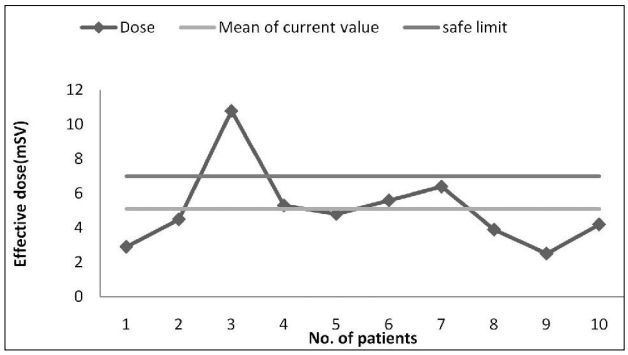

Figure 3: Effective doses measured from CT generated for chest procedure

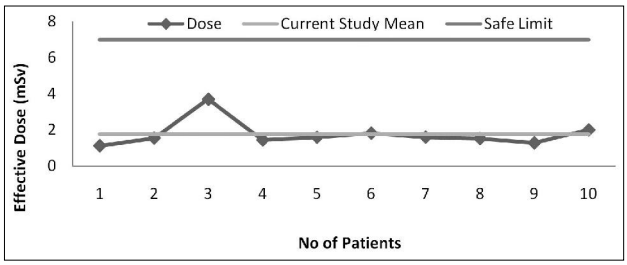

Figure 4: Effective dose measured with TLD for chest CT procedure

The overall mean doses for chest scan calculated from CT dose index was 8.82 ± 2.09 mGy and measured with TLD found to be 15.73 ± 5.2 mGy shown in (Tab. 4). The overall mean effective dose calculated from CT dose index and measured with TLD for chest examination found 5.64 ± 0.913 mSv and 1.780 ± 0.75 mSv respectively.

Measured CT generated mean dose (mGy)	Measured TLD Mean dose (mGy)	Calculated mean effective doses (mSv)	Measured mean effective doses (mSv)
8.823 ± 2.0939	15.73 ± 5.2	5.644 ± 0.913	1.7803 ± 0.754

Table 4: Overall mean measured doses and effective doses generated by CT and TLD for chest scan

Mean height, weight, age, sex related to selected patients for chest CT examinations and different parameter related to CT scanner are shown in (Tab. 5). DLP calculated effective doses due to CT scanner and TLDs for chest CT are shown in (Tab. 6). CT Doses outside the exposed field (eye in case of chest CT procedures) were measured using TLDs are also given in (Tab. 6).

Sex	Age(y)	Height (cm)	mAs	CTDI (mGy)	Dose (mGy)	Scan time(s)	Pitch	Slice (mm)
Male	45.25	155	167	13.28	17.08	17.31	0.5	5
Female	48.16	165	104	9.72	12.49	12.79	0.5	8

Table 5: Parameter related to CT and patient information for chest CT

Gender	DLP (mGycm)	Dose on the eye due to chest CT (mGy)	Effective doses of CTDI (mSv)	Effective dose of TLDs (mSv)
Male	513.0	1.87	6.0	2.2
Female	48.16	2.24	4.6	1.4

Table 6: DLP, calculated effective doses due to CT scanner and TLDs for chest CT

Estimation of cancer risk for chest CT procedure
Cancer risk was also assessed for chest CT procedures, in this regard average age and average effective dose for male and female patients were calculated separately. The estimated doses lead to the development of a cancer varied widely depending on the specific type of CT examination, patient's age and sex. Average age in the present study for male patients was 45.25 yr (26-60 yr). The calculated average effective dose for CT and TLD found to be 6.0 and 2.20 mSv for male patients. The cancer risks calculated from the measured doses for male patients having chest examination were 1 in 2893 and 1 in 1972 persons for CT and TLD procedures. The average age of female patients was 46.8 yr (28-58 yr) and average effective dose for CT and TLD came out to be 4.6 and 1.4, respectively. The cancers risk for female patients calculated on the basis of measured doses were 1 in 481 and 1 in 1896 individuals for CT generated doses and TLD procedures.

Conclusion

Radiation doses measured from selected procedures in diagnostic CT examinations from CT derived parameters and TLD. Based on measured data lifetime excess cancer risks for head and chest CT scans were calculated. The mean effective doses for CT generated and TLD found to be 1.8 and 0.47 mSv for male and 2.0 and 0.4 mSv for female patients respectively. The calculated average effective dose for CT and TLD found to be 6.0 and 2.2 mSv for male patients and 4.6 and 1.4 for female patients in chest CT examination. It is concluded that patient undergoing CT examination at NORI have doses within the recommended dose limits and variable within the same examinations.

References

1. Mettler FA Jr., Thomadsen BR, Bhargavan M et al. Medical radiation exposure in the U.S. in 2006: preliminary results. Health Physics 2008; **95(5):** 502-7.

2. Wiest PW, Locken JA, Heintz PH, Mettler FA. CT scanning: a major source of radiation exposure. Semin Ultrasound CT MR. 2002; 23(5):402-410.

3. Lewis MA, Edyvean S. Patient dose reduction in CT. Br J Radiol. 2005; **78:** 880-3.

4. Gonzalez AB, Mahesh M, Kim KP et al. Projected cancer risks from computed tomography scans performed in the United States in 2007. Arch Inter Med. 2009; **169(22):** 2071-7.

5. Shrimpton PC, Hillier MC, Lewis MA, Dunn M. Doses from computed tomography (CT) examinations in the UK-2003 review (NRPB-W67) Chilton: NRPB; 2005.

6. Olerud HM. Analysis of factors influencing patient doses from CT in Norway. Radiat Prot Dosimetry. 1997; **71:** 123-33.

7. BEIR-VII. Biological Effects of Ionizing Radiation. Health risks from exposure to low levels of ionizing radiation. National research Council, National Assembly Press 2005.

8. Aldrich JE, Bilawich AM, Mayo JR. Radiation doses to patients receiving computed tomography examinations in British Columbia. Can Assoc Radiol J. 2006; **57:** 79-85.

9. ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann. ICRP 2007; **37:** 2-4.

10. Tack Group on Control of Radiation Dose in Computed Tomography. Managing patient dose in Computed Tomography. A report of the ICRP. Ann ICRP. 2000; **30:** 7-45.

11. Brenner DJ, Elliston CD. Estimated radiation risks potentially associated with full body CT screening. Radiol. 2004; **232(3):** 735-8.

12. Commission of the European Community. European guidelines on quality criteria for computed tomography. 1999. Report EUR 16262 EN.

13. UNSCEAR 2000. The United Nations Scientific Committee on the Effects of Atomic Radiation. Report to the General Assembly. New York United Nations 2000.