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CT Simulation Effective Doses of Breast Cancer Patients and Chest CT Effective Doses Measurements for a Particular Healthcare Institute of Bangladesh

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Abstract

CT scan has become a popular tool, widely used in detection, monitoring and guide procedures like biopsy, radiotherapy etc. Simultaneously, this technique yields to high radiation exposure to the patient body along with its beneficial purposes. The Dose Length Product (DLP) of breast cancer patients during Computed Tomography (CT) simulation and normal chest CT scan were measured to calculate patient effective dose. Effective doses from CT simulations of breast cancer patients have been measured. From this data, a radiation risk assessment has been developed between the two tests, CT simulation for therapeutic purpose and Chest CT scan. Forty nine female patients were introduced for CT simulation. Volumetric CT Dose Index ($CTDI_{vol}$) was 13.1 mGy using 32 cm phantom as reference. The length of neck, chest and abdomen was 11.29 ± 2.22 cm, 22.15 ± 2.40 cm and 10.43 ± 4.54 cm respectively. From CTDIvol and length the calculated DLP of neck, chest and abdominal region were 136.67 ± 59.45 mGy.cm, 290.22 ± 31.54 mGy.cm and 147.87 ± 29.13 mGy.cm. Effective dose for chest CT and CT simulation of breast cancer patients were as follows: chest CT 4.06 ± 0.44 mSv and CT simulation 7.89 ± 0.86 mSv. For comparative T-test of effective doses the p-value was<0.001. The results of this study will facilitate establishing Diagnostic Reference Levels (DRLs) of effective dose due to CT simulation of breast cancer patients and chest CT scan in Bangladesh.

Keywords: Effective dose; Dose length product; CT stimulation; Diagnostic reference levels

Introduction

After introducing Computed Tomography in diagnostic radiology, the most widely used imaging modality is still CT **[1]**. Radiation doses in CT are larger than conventional X-ray imaging techniques **[2]**. As a high dose diagnostic procedure CT has been classified by the European Union ionizing radiation protection directive and suggested to optimize the patient dose **[3]**. So the risk analysis and understanding patient population dose is a timely topic as ionizing radiation may cause cancer **[4]**.

Stochastic effect and deterministic effect are two major types of risk in ionizing radiation **[5]**. For risk analysis, the patient population effective dose measurement has become a popular technique; moreover it will be used to conduct associative effective dose values with other known or relatable population effective dose values **[6]**. Effective dose shows only the value considering given exposure conditions, not the characteristics of a specific individual.

Effective dose describes the somatic dose development where differences in biological tissue sensitivity to ionizing radiation are reflected **[7]**. For human body, the weighted summation of measured organ dose (DT,R) is defined as effective dose $\left(E = \Sigma\Sigma W_T W_R D_{T,R}\right)$ **[8]**. Weighting factors vary according to different types of radiation and tissue types. The International Commission on Radiological Protection (ICRP) introduced the tissue-weighting factor to calculate effective dose. The updated weighting factors for 30 organs and tissues of the human body were published in 2007 by ICRP **[9]**. Software based Monte Carlo methods and Dose-Length Product

(DLP) with sets of age and body region specific k-factors are two common practices to calculate effective dose for CT **[10**,11]. Initially, the data used to derive k-factors were collected from the united kingdom's national radiological protection board monte carlo organ dosimetry program developed in 1991 and updated in 2002 **[12,13]**. DLP denotes the total amount of radiation used during CT scan and it is calculated by multiplying $CTDI_{vol}$ with scan length. $CTDI_{vol}$ expresses the intensity of the radiation emitted by a CT device. It describes the radiation exposure on average per-section in reference to 16 cm or 32 cm cylindrical phantom that's why $CTDI_{vol}$ is not related to patient size, it does not show the actual amount of radiation the patient is being exposed to **[14]**.

About 60% of the patients treated at Institute of Nuclear Medical Physics (INMP) are afflicted with carcinoma in breast. In modern radiotherapy techniques CT simulation is the prerequisite for contouring, treatment planning and treatment delivery procedure. Patients may have regional or distant metastasis, so at time of CT simulation of breast cancer patient's the scan area is considered from nose to abdomen which is larger than normal chest CT scan area. After successful completion of radiotherapy, very few of the patients came with secondary carcinoma which may have occurred due to radiation effect of radiotherapy or radiation of CT simulation. For risk analysis of radiation induced carcinoma a proper radiation monitoring is necessary either the radiation exposure due to therapy or CT scan.

The purpose of this study was to measure the DLP of breast cancer patients during CT simulation and normal chest CT scan at INMP to calculate and compare effective doses. These radiation dose parameters could be used to set Diagnostic Reference Levels (DRLs) in Bangladesh. Only adult female patients are considered in our study.

Experimental Methods

Patient setup for CT simulation

To determine the exact location, shape and size of a tumor, CT simulation processes are carried out. The main purpose of CT simulation is to assist the radiotherapy team in the treatment planning process. In 2021 around 60 breast cancer patients were subjected to CT simulation for radiotherapy purposes at Institute of Nuclear Medical Physics (INMP). Effective doses were calculated from 49 breast cancer patients who underwent CT simulation. The average age of the patients were 47.2 (± 10.4) years. All patients were scanned using a helical CT, Philips ingenuity TF PET/CT system. The patients are placed on the couch in a Plexiglas cradle gripping vertical handles above the head in a comfortable position **[15]**. The device was fitted in a 70 cm bore of CT gantry. For isocenter definition and to define caudal and cephalad margins of the tangential fields radio-opaque markers were appointed on the patient's skin. When the image reconstruction had been completed, for treatment planning and treatment the isocenters and alignment points were sketched on the patient's skin **[16]**.

CT Simulation Parameters

A CT scanner with flat table top, laser positioning and marking system, simulation software, hardcopy output CT-linked 3D treatment planning system are combinedly make a CT simulator **[17]**. Rather than a dedicated CT-simulator at INMP we used a 128 slice PET-CT system (Philips Ingenuity ToF) for CT simulation. The detailed parameters of our system during CT simulation were as follows (Table1).

CT Parameters	Value	CT Parameters	Value
Slice thickness	2.5 mm	Detector Coverage	40 mm
Tube Voltage	120 kV	Pitch	0.704
Tube Current	200 mAs	Gantry Rotation Time	0.4 sec
Field of View	700 mm	Table Speed	67.0 mm/sec
iDose Level	3	CTDIvol	13.1 mGy
CTDIvol, volumetric computed tomography dose index.			

Table 1: CT simulation parameters.

Data Acquisition from CT Console

The patients were introduced into a rotating x-ray beam and detector set in helical CT at INMP. The x-ray beam from the CT tracks down a helical path in the patient viewpoint. Then three dimensional data sets for the consequence of helical path were reconstructed into sequential images for a stack **[18]**. Among 60 patients, for our study purposes we selected 49 patients by excluding those who had multiple metastasis covering nearly the entire body. Radiation oncologists guided us to set the CT scan area. Since patients may have regional or distant metastasis, at time of CT simulation of breast cancer patient's the scan area is considered from nose to abdomen. Scans were performed by maintaining tube potential 120 kV which is our regular practice except bulky patients. Radiation dose parameters of CT simulation were collected from the console computer. For CT simulation of breast cancer patients 32 cm phantom size was

taken as reference. Volumetric CT dose index (CTDIvol) was recorded.

Data Acquisition from TPS

The first step in the treatment planning process is patient data acquisition. Therefore, CT simulated data is imported to the treatment planning system which was sent from the CT console. Oncologist contoured the Gross Tumor Volume (GTV), Clinical Target Volume (CTV). Physicists defined the Planning Target Volume (PTV) and made the plans for the treatment. At INMP Somavision software is used for contouring and Eclipse 13.7 is used for treatment plans. Plans were approved and patients were treated accordingly. Later for the study purpose oncologists copied the CT image series and contoured the normal chest CT scanning area **[19]**. On the basis of that contouring, the neck and abdominal portion were fragmented. The length of neck, chest and abdominal region were measured by using distance measuring scale in TPS software. These body region specific lengths were used to calculate Dose Length Product (DLP) and Effective Dose (ED) (Figure 1).

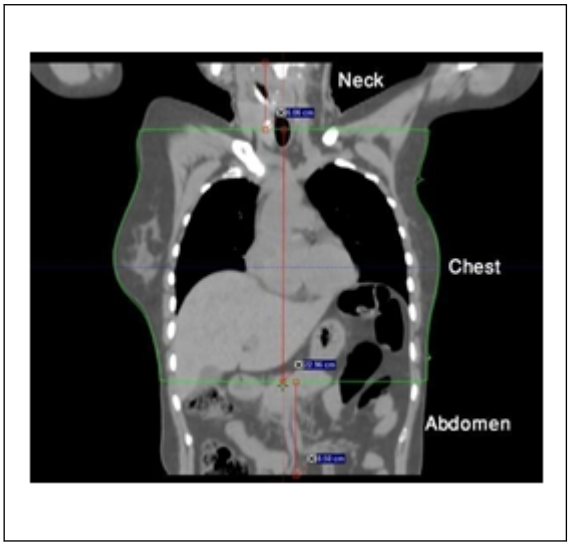

Figure 1: Contouring on CT simulated image to define different regions.

Effective Dose Measurements

DLP is the parameter which represents all the energies absorbed in the phantom bearing the unit mGy.cm **[20]**. Effective doses were calculated by using DLP and sets of age and body region specific k-factor using following equation **[21]**

$$E = k \times DLP$$

Where, k is coefficient of unit mSv/mGy.cm to convert DLP into effective dose and DLP is the product of $CTDI_{vol}$ and scan length.

Statistical Analysis

We made a comparison between effective dose of CT chest and effective dose of CT simulation and calculated their average and standard deviation. For comparison we also performed a statistical analysis named T-test. P value of less than 0.05 was considered to indicate a statistically significant data comparison for 95% data. MS Excel and SPSS software (version 25, IBM corporation) were used for data analysis.

Results

49 CT simulations were performed where all the patients were female. The mean ± SD age of the patient who underwent CT simulation was 47.22 ± 10.36 years (minimum and maximum age was 25 years and 73 years respectively).

$CTDI_{vol}$ and DLP

$CTDI_{vol}$ was 13.1 mGy using 32 cm phantom as reference. Length of the chest region was measured 22.15 ± 2.40 cm. From $CTDI_{vol}$ and chest length the calculated DLP for the chest region was 290.22 ± 31.54 mGy.cm. Due to CT simulation of breast cancer patients for radiotherapy extended areas were administered for CT. The average length of neck and abdominal region was 11.29 ± 2.22 cm and 10.43 ± 4.54 cm respectively. In those cases the DLP for neck and abdominal region was 136.67 ± 59.45 and 147.87 ± 29.13 mGy.cm.

Effective Dose

Effective dose for chest CT and CT simulation of breast cancer patients were as follows: chest CT 4.06 ± 0.44 mSv and CT simulation 7.89 ± 0.86 mSv. For comparative T-test of effective dose the p-value was <0.001(Figure 2)

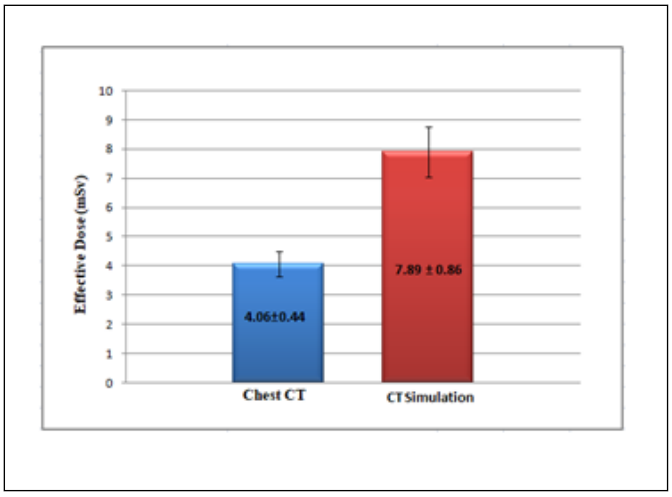

Figure 2: Comparison of Effective Dose between Chest CT and Breast Cancer CT Simulation.

Discussion

In this study, radiation dose parameters of the breast cancer patient's CT examinations of a single center in Bangladesh are reported. Cancer risk of CT examinations is reflected by the description of effective dose value. Several former studies clearly depict that the effective dose can easily be estimated from the DLP by multiplying with a suitable k-factor for different body regions **[22]**. Age and gender have also been accounted for k-factor values.

According to the latest publication of International Commission on Radiology Protection (ICRP), DRLs is the inspection tool to help in optimization of protection from ionizing radiation exposure in clinical diagnostic and interventional procedures.

Particularly high or low radiation dose in routine examinations for a speci ied test can be evaluated from this. In this publication typical radiation dose parameters are de ined as the mean ± SD of the total data for a DRLs quantity from CT examinations in a particular institution. To set the local DRLs minimum 10 institutions are needed.

Three radiation dose parameters $CTDI_{vol}$, DLP and Effective dose are reported where $CTDI_{vol}$, DLP, and Effective dose are measured in milligray (mGy), milligray.cm (mGy.cm), and millisievert (mSv), respectively. Among these the $CTDI_{vol}$ and DLP are collected from CT instruments using proper patient protocol. To compare radiation doses with national and international DRLs in CT test, the above mentioned three parameters can easily be used.

Primarily the intensity of the radiation emitted by a CT device is indicated by $CTDI_{vol}$ where 16 or 32 cm cylindrical phantom is used as reference. Normally 32 cm phantom is used for chest and abdomen scan of adults and 16 cm phantom is used for head & neck and pediatric patients **[23]**.

But in our calculation we selected 32 cm phantom as a reference for neck study also because we performed CT simulation from abdomen to nose in a single scan. According to walter huda to measure the effective dose of the neck region by using 32 cm phantom as a reference instead of 16 cm phantom the DLP value connected with 32 cm phantom was multiplied by two **[24]**.

In reference to the USA data, the effective dose value for chest CT of our institute (4.06 ± 0.44) is signi icantly lower than USA value (9 mSv) **[25]**, meanwhile, the effective dose for breast cancer CT simulation (7.89 ± 0.86) is also lower than usa chest CT value (9 mSv). Compared to European (6.6 mSv) and worldwide (7 mSv) effective doses of chest CT, at our institute the effective dose of chest CT (4.06 ± 0.44) is lowered by around 3 mSv **[26, 27]**, whereas the effective dose for CT simulation of breast cancer patients (7.89 ± 0.86) is higher than European and worldwide E value of chest CT (Figure 3).

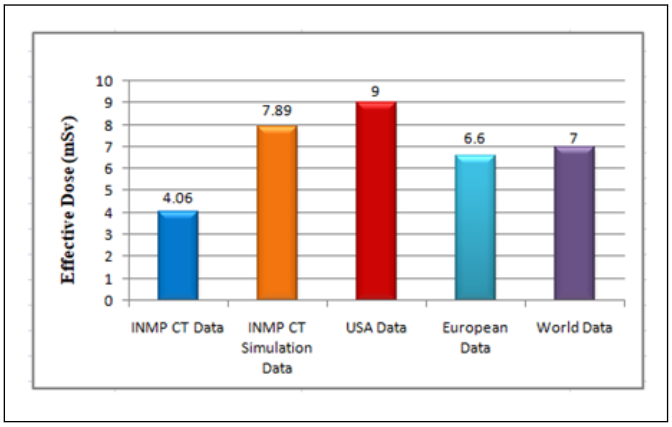

Figure 3: Comparison of effective dose among INMP, USA, European and world data

To calculate effective dose from DLP, in our study we used the conventional k-factors derived using tissue weighting factors of ICRP report 103 considering adult patients which are as follows: for chest region 0.014 mSv/mGy.cm, for abdomen 0.015 mSv/mGy.cm and for neck area 0.006 mSv/mGy.cm **[28]**. But the existing k-factors derived with two limitations as keeping lack of realism the anatomical structures described by mathematical equations and stylized phantoms used as a reference are smaller or larger than the real patients **[29]**. In conventional morphological study, the average height and waist diameter of Bangladeshi females is smaller compared to larger physiques of European females, that's why the measured effective doses value in this study may have anomalies. To get more accurate data, first of all we need to estimate a size specific k-factor compatible with Bangladeshi females and this is a scope for further study regarding this work.

Conclusion

The evaluation of patient doses has been executed for CT simulation of breast cancer patients and normal chest CT scan. Effective dose for CT simulation is nearly doubled compared to chest CT scan. Smaller spatial size while considering organs of interest is the prime reason for this aberration. In this study, absorbed and effective dose are determined regarding the patients of INMP, Bangladesh. Determination of effective dose for CT simulation of breast cancer patients is first time in Bangladesh, thus minimum nine more institutional patient data is required to establish the national DRLs value for Bangladesh.

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