

Assessment of Organ Dose and Effective Dose from Head CT Examination in a Large Hospital in South-Southern Nigeria

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Abstract

The magnitude of radiation dose imparted to patients who underwent Head Computed Tomography examination in a large tertiary hospital in South-Southern Nigeria has been estimated. CT-ExPO dosimetry software was used to determine the effective and organ doses to the head region of 40 adult patients. Scanning parameters were retrieved from the CT monitor for both contrast-enhanced and non-contrast head CT examinations. The tube potential ranged from 100 kVp to 120 kVp, while the mAs ranged from 127 mAs to 202 mAs. The mean values of the volume Computed Tomography Dose Index (CTDI_{vol}) and Dose Length Product (DLP) for the contrast-enhanced Head CT examination were 166.4 ± 39.6 mGy and 3568.6 ± 756.1 mGy-cm, respectively, while for the non-contrast examination they were 86.6 ± 30.4 mGy and 2102.3 ± 870.3 mGy-cm, respectively. The effective doses were higher for the contrast-enhanced study than for the non-contrast study by a factor of 1.6. Results were compared with the European Union reference doses and other published data and were found to be higher. Doses to the organs which comprise of brain, red bone marrow, thyroid and eye lens were also estimated. The high variation in the doses in this study may be due to differences in imaging protocols such as large range of mAs and scan lengths and also the algorithm of the scanner.

Keywords

Computed Tomography Dose Index, Dose Length Product, Organ Doses, Effective Dose, CT-ExPO Software

1. Introduction

Ionizing radiation has been a major source of concern since the advent of x-rays,

mammography and computed tomography examinations. Computed Tomography (CT) examinations which use x-rays to make detailed pictures of structures inside the body constitute the largest contribution to radiation exposure of the population thereby making diagnostic medical x-rays the largest man-made source of ionizing radiation exposure [1]. Despite its large contribution to medical radiation exposure, the superiority of CT scanning over conventional radiography is based on the fact that

1) It has the ability to eliminate organ or structural super-imposition that usually occurs in conventional radiography.

2) As a digital modality, it has also the potential of producing diagnostic quality images with almost unlimited radiation doses since detectors are linear over long ranges.

3) Operator dependency palpable in ultrasonography is absent in CT, as CT images are reproducible.

4) It has better cortical bone definition and readily displays calcification unlike MRI [2].

Increase in the use of CT for diagnostic imaging is well documented; likewise the associated increase in radiation risk for patients undergoing CT investigations [3]. The increased use of ionizing radiation in diagnostic imaging, the rapidly expanding use of CT in the emergency setting, the introduction of multi-detector CT units and newly reported concerns related to the human consequences of low-level radiation exposure have revitalized a long-standing concern over the quantification and management of an individual's cumulative medical radiation exposure [4]. Studies have shown that many physicians, including radiologists have developed a misconception that the shorter imaging acquisition times have resulted in lower doses of radiation, when in fact, many times, the opposite is true. Body parts located in the central part of the body (chest/abdomen and pelvis) generally require higher levels of radiation exposure in order to obtain adequate imaging [5]. There is a small, theoretical risk of carcinogenesis attributable to low doses of ionizing radiation based on epidemiological evidence at higher doses and dose rates. Many studies have investigated the correlation between radiation exposure and cancer risk. Epidemiological studies, such as life span study of the atomic bomb survivors, medical studies and experimental animal research have established a relationship between exposure, cancer induction and cellular damage. However, there is lack of consensus on the effects of radiation at low doses and low dose rates, with the linear no threshold hypothesis being widely accepted and the basis of the international system of radiation protection [6]. Tissue reaction effects have precise radiation dose thresholds which induce radiation risks in relatively high doses [7].

Radiation doses associated with commonly used CT examinations resemble doses received by individuals in whom an increased risk of cancer had been documented [8] [9]. A single CT scan can deliver an equivalent radiation exposure and patients may receive multiple CT scans over time [10]. Even though the

risk to an individual patient may be small, the increasingly large number of people exposed, coupled with the increasingly high exposure per examination could translate into many cases of cancer resulting directly from the radiation exposure from CT. It is important to understand how much radiation medical imaging delivers, so this potential for harm can be balanced against the potential for benefit. This is particularly important as the threshold for using CT has declined, and CT is increasingly being used among healthy individuals, where the potential for carcinogenesis could outweigh its diagnostic value [11].

The head CT scan has been the most common CT examination performed in Europe (30% - 40%), for more than a decade, and it also contributes significant total collective effective dose to the population [12]. Likewise in Nigeria, head CT examinations is the commonest CT examination performed in most CT centres. The significant radiation dose delivered to superficial radiosensitive organs, such as lens of the eye, unavoidably irradiated during radiological procedures of the head, is also a concern. Even though, there are non-ionising imaging modalities, such as magnetic resonance imaging that are currently used for imaging of the head, CT imaging continues to be on the increase due to its wide availability and clinical application. It is impractical to directly measure the radiation dose absorbed by individual patients even when the radiation emitted by a machine is precisely known. Instead, radiation exposure may be quantified using various methods. The evaluation of effective dose, E, in diagnostic radiology is an important tool for risk estimates from medical exposures. This is one of the most frequently reported measurements [6]. Further, effective dose allows comparison across the different types of CT studies and also between CT and other imaging tests, facilitating comparison of CT to the most common radiology examinations that patients undergo. The effective dose accounts for the amount of radiation to the exposed organs, and each organs sensitivity to developing cancer from radiation exposure. Hence, the benefit derived by patients should far outweigh the associated risk when the imaging is properly conducted. This study, therefore, aims to assess how much radiation exposure has been imparted to patients during head CT examinations at a large tertiary hospital in the South-Southern region of Nigeria.

2. Materials and Methods

This study involved 40 adult patients of mixed gender (25 males and 15 females) referred for head CT scan at a large tertiary hospital in the South-Southern region of Nigeria. Their ages ranged from 18 to 82 years with a mean of 48 ± 17.6 years. Ethical approval was obtained from the local ethics committee of the hospital. Computed tomography examination of the head was the most frequently requested examination at this hospital, therefore, scan-specific parameters for this examination were collected. Displayed CT console measurements of $CTDI_{vol}$ and DLP along with records of each patient's scanning parameters were obtained from the Toshiba 16-slice Aquillion CT equipment used at the hospital. Organ

and effective doses were estimated using CT-ExPO (version 2.5) dosimetry software. The organ doses to the brain, eye lens, red bone marrow (RBM) and thyroid were estimated from the head CT examination. The prospective study comprising of contrast-enhanced and non-contrast Head CT examinations lasted for 3 months. The CT-ExPO software is based on Monte Carlo data sets and has a unique feature of organ dose calculation for specific gender. For the head scan region, the following exposure parameters were obtained from the CT scanner used: tube voltage, tube current, scan range, rotation time, spiral pitch, and collimation. The tube potential ranged from 100 kVp to 120 kVp, while the mAs ranged from 127 mAs to 202 mAs. The mean exposure parameters used for the examinations under study are presented in **Table 1**.

3. Results and Discussion

The demographic and dose characteristics of patients are presented in **Table 2**. The mean values of the volume Computed Tomography Dose Index (CTDI_{vol}) and Dose Length Product (DLP) for the contrast-enhanced Head CT examination were 166.4 ± 39.6 mGy and 3568.6 ± 756.1 mGy-cm, respectively, while for the non-contrast they were 86.6 ± 30.4 mGy and 2102.3 ± 870.3 mGy-cm, respectively. **Table 3** compares the CTDI_{vol} and DLP from this study with published data and European Union (EU) reference doses for head CT examinations (no contrast). The CTDI_{vol} and DLP were higher than the EU values by factors of 1.4 and 2, respectively. **Table 4** shows the comparison of estimated effective doses for contrast-enhanced and non-contrast Head CT examinations in this study with published data and EC reference values. The effective doses were higher for the contrast-enhanced study than for the non-contrast study by a factor of 1.6. Comparisons of the mean effective doses from this study with previous studies, in a large tertiary hospital in south-western, Nigeria showed a large difference up to a factor of 3.6 [13]. The effective dose from the non-contrast CT was also higher than EU reference value by a factor of 5.

Doses to the organs which comprise of brain, red bone marrow, thyroid and eye lens were 83.2 mGy, 7.9 mGy, 5.2 mGy, and 107.6 mGy, respectively for contrast-enhanced studies whereas, for non-contrast studies they were 79.8 mGy, 7.7 mGy, 5.0 mGy, and 105.8 mGy, respectively. The organ doses to the

Table 1. Mean Head CT scan technique parameters in the hospital.

Exposure Parameters	Mean
Tube voltage	119 kVp
Tube current x time	195 mAs
Pitch	0.5
Rotation time	0.75 s
Scan length	20 cm
Slice thickness	4.9 mm

Table 2. Demographic and dose characteristics of patients.

Examination Type	No. of patients	Patient age (years)		Effective Dose (mSv)		
		Range	Mean	Range	Mean	75 th percentile
Contrast-enhanced	25	18 - 82	48 ± 17.6	11.7 - 26.0	15.3 ± 3.2	16.1
No contrast	15			2.2 - 19.3	9.2 ± 3.8	10.0

Table 3. Comparison of mean CTDI_{vol} (mGy) and DLP (mGy-cm) for no contrast examination with previous studies and EU reference values.

Dose indices	This Study	[13]	[12]	[14]	[15]
CTDI _{vol}	86.6	73.5	77	52.2	60
DLP	2102.3	1898	985	841.5	1050

Table 4. Comparison of effective dose E (mSv) with previous studies and EC reference value.

Examination Type	This Study	[16]	[13]	[17]	[15]
Contrast-enhanced	16.1	6.1	-	-	-
No contrast	10.0	3.1	2.8	1.8	2.0

brain and eye lens were factors of 2.9 and 1.9 higher, respectively, when compared with values of organ doses obtained by [18]. The doses to the brain and eye lens during head CT examination in this large tertiary hospital appear to deserve attention. The high variation in doses in this study may be due to differences in imaging protocols such as large range of mAs and scan lengths and also the algorithm of the scanner. These findings strongly justify the need for immediate optimization of protocols at the hospital.

4. Conclusion

Organ doses and effective doses from head CT examinations in a large tertiary hospital in South-Southern Nigeria have been determined using the CT-ExPO dosimetry software. A significant variation was observed between this study and published data including EC reference values. An immediate intervention modality to harmonize CT protocols has become pertinent in Nigeria in order to optimize the doses delivered to patients during CT examinations. Periodic patient dosimetry evaluation and quality assurance programme should be an essential part of every radiological department of a hospital.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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