International Journal of Scientific Research in Physics and Applied Sciences **Research Paper**
Vol.9, Issue.4, pp.42-46, August (2021) **E-ISSN:** 2348-3423

Computed Tomography Dose Measurement in Three Hospitals of Pokhara

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Received: 01/Jul/2021, Accepted: 07/Aug/2021, Online: 31/Aug/2021

Abstract— Within a second the Computed Tomography (CT) can produce a details image of any part of body and provide valuable diagnostic information for treatment planning. CT Dose Index (CTDI (vol)) and the Dose Length Product (DLP) measured in Mille Grey (mGy) and mGy-cm, respectively are used to measure radiation exposure to the patient. In this study, the effective dose for different CT scanner have been calculated, in some of the hospitals in Pokhara, for head, chest, and abdomen scan during the month of July 2019. Three CT scanners (2, 16, and 128 slice) were chosen, each having different operating protocol and number of detector. 128 slice CT scanner can be noticed as high radiation risk for patient among three CT type. In case of head, the calculated effective dose for each three scanner result 1-2 mSv, same as the reference dose value. As scan length of target area varies, the corresponding value of dose also gets varied. This work surveys the absorbed radiation dose on the basis of scan length in sample scan cases.

Keywords— CT Scanner, Effective Dose, Radiation

I. INTRODUCTION

Computed tomography (CT) has a remarkable breakthrough in medical diagnostic for variety of clinical applications. The word Tomography is taken from Greek word “tomos" which mean “slice" or “section” and “graphia" mean “describing" [1]. A CT is a scanner which use X-ray source, a detector, and control computer system to reconstruct image of different body parts. Images are integrated by rapid 360^o rotation of the X-ray tube around the affected organs. The transmitted radiations through patient’s body are stored by ring of sensitive radiation detectors located on the gantry. These images are transferred to a computer, where they are combined to create (3D models) images of cross-sections of the body.

Godfrey Newbold Hounseld is known as father of CT scan, constructed the prototype of first medical CT scanner at EMI Central Research Laboratories using X-ray technology and later in 1979, he was awarded by Nobel Prize on Physiology and Medicine [2]. A CT scan has wide applications, people who have internal injury from accident or trauma, go through CT scan procedure for treatment planning. Images from CT scan visualize disease or injury at all parts of body and provide best treatment plan. CT scan has huge advantages for detecting cancers in the chest, pelvis, liver, kidney, ovary, and pancreases. It provides a 3D image that allows a physician to confirm the tumor size, identify its exact position, and define the extended associations in nearby tissues. CT depicts the limitation of conventional radiography creating 3-D image along the ability to differentiate the body parts accordance with densities.

In radiation safety procedure, Dose is the amount of energy deposited per unit mass of tissue due to the ionizing radiations. Although CT has huge contributions in modern health care, some attenuation of ionizing radiation received during CT examination can be categorized as health hazard. During the scan, patients are affected by the X-ray beam and the energy is dropped in irradiated organs. The absorbed dose is the measure of amount of energy set down per unit mass of the tissue at the time of exposure. Effective Dose (ED) is used to assess the indication of potential long term effects such as risk of carcinogenic and genetic abnormalities [3].

Mostly, medical physicist and radiologist measure the value of Effective Dose (ED) from the Monte Carlo dose simulation tools from prototype of human phantoms. But practically, in treatment planning, we estimate the effective dose from dose-length product (DLP). This method gives more accurate value of EDs, which is calculated by using the DLP displayed on the CT console at the end of any scan examination. The product of CTDI (vol) and scan length give the value of DLP, which is the total amount of radiation delivered [4]. The effective dose estimates how much radiation is received by a patient's tissue in accordance with its sensitivity [5]. All the types of CT scanner have their own scan protocol for particular part of body examination, with the set value of voltage, MAs, tube current ,tube potential, slice width, rotation time etc.

Computed tomography (CT) is the top listed contributor of effective dose among all the radio-graphic procedures. CT examination represents 11% and 4% among all medical imaging procedures in United States and Europe, but if we consider radiation dose perspective CT effective dose contributes almost 67% and 40% to the total collective dose from all medical radio-graphic procedures [6]. CT consists of high quality of X-ray imaging technique to secure the substantial treatment benefits and the most of the examination deliver nearly 10 mSv effective dose to the patient [7]. A study of CT examination among 630 patients undergoing head 97, chest 243, and abdomen 293 estimated 1.2 ,5.9, and 8.2 mSv dose value for head ,chest, and abdomen, respectively [8]. A similar research work in USA recorded median dose value as 2 (2-3) mSv for head, 8 (5-11) mSv for chest, and 15 (10-20) mSv for abdomen among 1119 CT examination [9].

The remainder of the paper is organized as follows: in section II and III, the detailed information of measurement techniques and methods of the study are described, respectively. The results and discussion with possible clarification are provided in section IV. Finally, in section V, the results of the study are concluded.

II. MEASUREMENT TECHNIQUES

The measured quantity of effective dose provides the level of radiation risk in a patient during CT examination. Actually, effective dose is related to the carcinogenic risk simply known as a long term effect on the tissue. Generally, the effective correspond the stochastic risk because of exposure to ionizing radiation. According to the International Commission on Radiological Protection, effective dose signifies a weighted sum of the equivalent doses in all tissues and organs of the body, where the equivalent dose for an organ represents the sum of the absorbed dose averaged over a tissue or organ weighted by the radiation weighting factor [10].

Both CTDI (vol) and DLP are machine parameters and do not reflect our required radiation dose. CTDI (vol) is a measurable parameter of CT dose from standardized phantom of a special protocol. It gives the average value of radiation dose within the exposed volume for an organ of similar attenuation to the CTDI phantom. Its value does not depend upon the length of scan, thus CTDI (vol) provides the total energy deposited on a single scan volume. Mathematically, it can be written as:

$$CTDI\ (vol) = \frac{1}{pitch} \times CTDI\ (w) \tag{1}$$

where,

$$CTDI\ (w) = \frac{1}{3}\ CTDI(100; center) + \frac{2}{3}\ CTDI(100; edge) \tag{2}$$

and the pitch is defined as table distance traveled in a complete 360° gantry rotation divided by total thickness of all simultaneously acquired slices. DLP represents the overall energy delivered by a given scan protocol:

$$DLP\ (mGv/cm) = CTDI\ (mGv)\ \times scan\ length \tag{3}$$

The estimated effective dose value from DLP method for a wide range of scan protocol can be compared with dose value derived from NRPB organ dose calculations and ICRP 60 tissue weighting coefficients, a linear relationship was found. Later on, European Commission presented a subsequent method to quickly estimate effective dose from CT examination [11]. By this method, we can calculate effective dose as follows: E = K × DLP, where K is conversion coefficient factor [12]. The Table 1 represents the respective value of convergence coefficient.

Table 1: Values of convergence factor for respective body part tissue, mentioned by EC Appendix C (2004) and NRPB-W67 (2005) [12]

Body parts	**Convergence factor (K)**	**Phantom (cm)**
Head	0.0021	16
Chest	0.014	32
Abdomen	0.015	32
Pelvis	0.015	32

For the head scan, the X-ray tube voltage (KVp) is independent of convergence factor but in case of body scan, KVp is dependent factor. For an increment in X-ray tube voltage from 80 to 140 KVp the corresponding differ in K factor will reach 4% [13]. The convergence factor (K) can be different with the patient age. K factor approximately, five times higher than the adults when we normalize the factor towards one for adults. There are number of factor at which CT dose values depend upon, they are the tube current and scanning time in milliamp-seconds (mAs), scan length, the scan pitch, the tube voltage in the kilo-volt peaks (kVp), and the special method of the scan being used. Most of the above mentioned factors can be controlled by the radiologist or radiology technician at the time of scan.

III. METHODS

The effective dose for different CT scanner around the Pokhara valley was calculated under head, chest, and abdomen scan during July 01 to July 30 2019. The selected 2 slice, 16 slice, and 128 slice CT scanner have different operating protocol and number of detector. Firstly, the scan summary was noted from each CT center for head, chest, and abdomen. The scan summary provided values of KVp, mAs, CTDI (vol), and DLP. For each machine, the scan length was reconstructed under same length which is a single parameter for our study. For head, chest, and abdomen, we had assigned 12 cm, 32cm, and 40 cm scan length, respectively. Finally, the effective dose was calculated for respective scanner in case of head, chest, and abdomen scan procedures. The convergence factor K was chosen according to the values specified in Table 1 and thus, compared to calculated dose values as suggested by the report published by American Association of Physicists in Medicine, as shown in Table 2.

Table 2: Typical effective dose values for several imaging exams [14]

Body parts	**Dose value (mSv)**
Head	1-2
Chest	5-7
Abdomen	5-7
Pelvis	3-4
Abdomen and Pelvis	8-14
Coronary CT angiography	5-15

IV. RESULTS AND DISCUSSION

In this study, we had collected the scan summary of adult examination from three different scan centers of Pokhara. We had collected similar summary from other two hospitals for head, chest, and abdomen. The DLP values, obtained from the observation, were converted into EDs by using the K factor.

Table 3: The table below shows the corresponding value of EDs for the CT examination under three different machines under study. The letters **H**, **C**, and **A** represent head, chest, and abdomen, respectively.

CT parameters	**Types of CT Machine**								
	128 Slices			**16 Slices**			**2 Slices**		
	H	**C**	**A**	**H**	**C**	**A**	**H**	**C**	**A**
KVs	120	120	120	120	120	120	130	130	130
MAs	501	250	250	250	150	200	240	32	58
CTDI (vol)	64.6	16.4	16.4	58.6	9.9	9.9	46.08	3	5.53
DLP	1576	525.8	818.9	702.7	286.2	468.3	552.9	112.1	225.9
ED	1.62	6.44	11.60	1.48	4.68	7.02	1.26	1.21	3.92

Obtained average value on Table 3 was compared with the dose value suggested by report AAPM (Table: 2). In case of head, the dose value exactly lies in 1-2 range provided by the report. But in case of chest and abdomen, these values vary slightly. The value of radiation dose depends upon the tissue sensitivity, that is how much the radiation absorbed by the tissue during the scan. Here, we had taken same scan length for an adult patient but in some case size of the patient cause problem. For example, a person with 6ft height and 5ft height has different size of chest and abdomen. Thus while scanning chest part, we may have to take some part of abdomen too while scanning the desire scan length. In each scanner, the abdomen part got high amount of dose than other parts. As scan length increases on going from head, chest, and abdomen, the corresponding value of dose also gets increased. In 128 and 16 slice scanner, the ED values for abdomen have high value 11.6 and 7.024, respectively than AAPM result. This is because of the some pelvic parts, come under while scanning which increase the scanning length. In each scanner, the abdomen ED is almost double than chest dose value. As we have higher number of slice the dose value is increased for each part of the body.

Generally, a human body receives a background radiation dose of 2.42 mSv per year [15]. A routine head CT dose is equivalent for 8-9 month background naturally occurring dose. But an abdomen CT dose 11.6 mSv (128 slice) is equivalent for 3 years background dose. The scanner at 128 slice and 16 slice set spiral/helical scan protocol and we can claim spiral technique responsible higher dose value [16]. The upgraded scanner, with better accuracy and high image qualities, may cause the variation on our estimated value and reference dose value. Progress in CT scan is guided by advancement in technology, spiral scan become more reliable than axial in diagnostic procedure. The technologist and physician prefer spiral examination to estimate the tumor and stone size in patient. But our study summarizes the patient has high risk of radiation while choosing standard multi slice CT, which are focussed on spiral scanning technique. Although the 2 slice scanner delivers minimum dose value to patient but for more accurate and precise treatment planning the medical person recommend multi slice scanner. It's hard to say 128 slice CT will be best because high dose signifies high radiation risk, we need to consider patient's health condition.

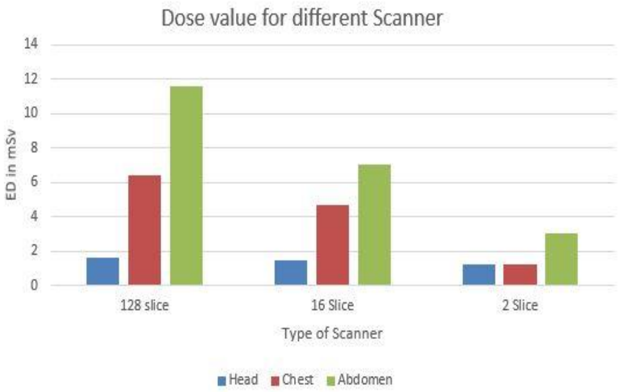

Figure 1: Respective dose value for different part of body in three different scanners.

During the medical procedure, the benefits must have to exceed the corresponding radiation risk. On the other hand, technologist must have to ensure no more amount of radiation is exposed that is needed for obtaining diagnostic information in any imaging procedure, especially in CT scan. Even if the technical difference among the chosen scanner, the operating parameters KVp, mAs setting, and scan length has huge importance to minimize the radiation dose in CT examination. It will be reasonable to reduce the mAs for the person thinner than average adult man size, minimize the scan volume in helical scan or lowering the number of slice in axial scan, the technologist can reduce the value of DLP and corresponding value of effective dose [17].

The dose of ionizing radiation delivered during CT scan could range from 50 to over 500 times that a stranded X-ray such as a chest X-ray or mammogram. It's become a most concern aspect that high amount of radiation and increasing number of scan may initiate a cancer risk in the benefited population. Thus, radiation dose measurement and its safety for patient as well as radiation worker have crucial aspect in CT examination. Some of scientific studies claim that the increase in CT examination causes the cancer and death of ten thousands of Americans in each year [9]. But there is no any scientific idea that can differentiate the cause of cancer either from induce radiation or from naturally occurring. It's hard to conclude that who is died from radiation cancer or naturally occurring cancer.

Despite in some examination, most of examinations of this study have similar result as in the report from American Physicist in Medicine published. Scan length has important role to regulate radiation exposure for the patient. Even though we have some limitations on selecting some scan parameters, we can suggest that the technologist should give more attention to review the scan practices to get optimum level of radiation dose. To reduce patient's dose value, technologist should limit the scan area within suspicious part and repeated scan should be avoided.

V. CONCLUSIONS

The Effective Dose measurements have been performed for three scanner models (128, 18, and 2 slice) through the concept of DLP method and prescribe value of convergence factor. For all three scanner models, the abdomen part prefers the maximum ED value than chest and head. It is shown that the patients who go through 128 slice scanner get significantly greater ED than 16 and 2 slice models. The calculated ED dose level for head exactly coincides with the reference value but in case of chest and abdomen parts, it slightly differs which is because of the scan length. It was estimated that CT patients in Pokhara mostly get 1 to 2 mSv, 1 to 6 mSv, and 3 to 11 mSv for head, chest, and abdomen, respectively. We suggest that the more attention should be given to reduce radiation risk during CT scan procedure.

ACKNOWLEDGMENT

We would like to thank Attma Ram Shah, Bashu Dev Poudel, Ashok Pokheral, Rajendra Prasad Koirala, Parshu Ram Poudel, Krishna Prasad Poudel, Tek Bahadur Khadka, and Binod Adhikari for their valuable technical support during this project.

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