Evaluation of Scattered Dose of Highly Radiosensivity Major Organ During Computed Tomography Examination

[1]Ki-Jeong Kim, Hong-Ryang Jung, Cheong-Hwan Lim, Gyoo-Hyung Kim, In-Seok Kang, Hye-Nam Lee

Abstract: Background/Objectives: We made an attempt to measure the scattering dose of space, surface, and deep region focusing on organs that are sensitive to radiation during CT examination and compare their characteristics. Methods/Statistical analysis: To conduct the experiment, we used 64-Slice MDCT for CT Scanner and Rando Phantom. For dose measurement, first, we used a Survey meter to measure space scattering dose, second, to measure incident surface dose, we used OSLD nanodot, and third, to measure deep dose, we used a glass dosimeter.The choice of the location for the measurement of radiation dose was based on organs that are susceptible to radiation, namely Orbit for Head, Breast for Chest, and Godnad for Abdomen.Findings: In the head CT scan, at breast,the space dose was 48.2 ± 0.34 μSv, the surface dose was 82.0 ± 2.29 μSv and the deep dose was 376.0 ± 1.58 μSv. In the Gonad, the space dose was 9.7 ± 0.02 μSv, the surface dose was 20.0 ± 1.36 μSv, and the deep dose was 12.0 ± 1.27μSv. In the chest CT scan, at orbit,the space dose was 229.0 ± 2.85 μSv, the surface dose was 167.0 ± 1.27 μSv and the deep dose was 506.0 ± 1.58 μSv. In the Gonad, the space dose was 72.6 ± 0.41 μSv, the surface dose was 96.9 ± 1.53 μSv, and the deep dose was 190.0 ± 1.58μSv. In the abdomen CT scan, at orbit,the space dose was 68.7 ± 0.34 μSv, the surface dose was 72.0 ± 1.36 μSv and the deep dose was 224.0 ± 1.58 μSv. In the Breast, the space dose was 145.2 ± 1.57 μSv, the surface dose was 4597.0 ± 1.27 μSv, and the deep dose was 9137.0 ± 1.27μSv

Improvements/Applications: It seems necessary to make constant efforts to reduce the dose of radiation by optimizing the radiation protection by blocking the space other than the main flux.

Keywords: Organ, Computed tomography, Scatter dose, Radiation sensitivity, Dosimeter

I. INTRODUCTION

Radiation is used in everyday life in many fields such as life sciences, logistics distribution, security search, and medical fields. This kind of use in the daily life has made the life of mankind convenient and enriching. It has also contributed a lot in helping to maintain a healthy life [1, 2]. Especially, the use of medical X-rays has increased with the extension of the life span and the improvement of the national income. According to the survey conducted by the MFDS (Ministry of Food and Drug Safety), the radiation dose per person increased by 51% over 5 years from 2007 to 2011 in the data of exposure dose increase. Not only that, in the number of radiation examinations in 2011, CT scans account for only 2.8%, but it accounts for 56% (0.79mSv) of the radiation dose per person for the whole country (1.4mSv), suggesting that radiation safety management is urgent [3]. In the field of diagnosis, CT examination has a large portion, and the number of CT equipment and the number of CT examinations are increasing year after year [4]. The American College of Radiology (ACR) states that, although CT scans should be performed for the benefit of the patient, for children or for the purpose of health examination, it should be carried out in consideration of its potential benefit and health hazard, emphasizing protocol management by experts and reduction of radiation dose through it. Also, in Europe and elsewhere, there is a growing demand for traceability of CT radiation dose in addition to the recommendation criteria for CT examinations [5, 6]. In Korea, as part of the measures to be taken in accordance with such demand, volume CT dose index (CTDI) and dose length product (DLP) of head and abdomen were presented in 2009 for the first time under the auspices of the NIFDS (National Institute of Food and Drug Safety Evaluation) through actual measurement of acrylic phantom and computed tomography dose index (CTDI) although somewhat limited [7]. Since 2012, guidelines for patient dose recommendations for pediatric radiologic examinations have been provided, and patient dose recommendations for pediatric head CT have been prepared for 103 CT scanners [8]. Although the radiation used at the clinic is low dose, there is a high risk of damaging the examiner, the patient and other workers due to the radiation exposure. If the X-ray irradiation is not restricted during the examination, it can have a decisive effect causing such diseases as erythema, cataracts, blood phase changes, lethality, and infertility. Since stochastic effects can lead to cancer, leukemia, genetic defects, etc., there is a need for thorough radiation safety management that can prevent and reduce such diseases [9]. For reduction of medical exposures,

Revised Manuscript Received on January 03, 2019.

Ki-Jeong Kim, Dept. of Radiology, Konkuk University Medical Center, KS013, Korea,

Hong-Ryang Jung, Corresponding Author, Dept. of Health Care, Hanseo University, KS002, Korea,

Cheong-Hwan Lim, Dept. of Health Care, Hanseo University, KS002, Korea,

Gyoo-Hyung Kim, Dept. of Radiology, Myong Ji Hospital, KS009, Korea,

In-Seok Kang, Dept. of Radiology, Incheon Christian Hospital, KS006, Korea,

Hye-Nam Lee, Dept. of Radiology, Kim sang young Internal Medicne clinic, KS002, Korea,

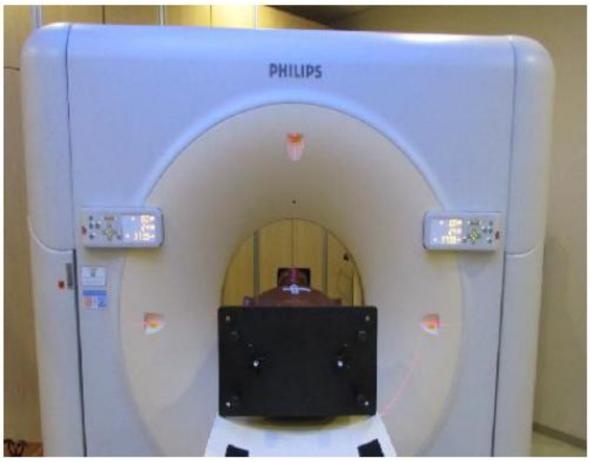
awareness and attitude toward radiation exposure of the radiologists conducting CT examination are very important factor, which has a great effect on minimizing patient exposure through radiation shielding [10]. Efforts to shield unnecessary radiation in the medical examination process using radiation are very important. The dose of radiation exposure can be reduced by artificial efforts, and the basic goal of radiation protection is to prevent the decisive effect from occurring to the exposed person in the context of considering the expected benefits from radiation exposure and to reduce the probability of stochastic effects to acceptable levels [11].

Accordingly, in this study, we made an attempt to measure the scattering dose of space, surface, and deep region focusing on organs that are sensitive to radiation during CT examination and compare their characteristics.

II. MATERIALS AND METHODS

2.1. Research equipment and materials

To conduct the experiment, we used 64-Slice MDCT (Multi-detector computed tomography, BrillianceTM, PHILIPS, Netherand) for CT Scanner [Figure 1-(a)] and Rando anthropomophic phantom (ART-200X, Fluke biomedical, USA) for Phantom in Figure 1-(b). For space scattering dose measurements, we used a Survey meter (X2 Survey, Unfors Raysafe AB, Sweden) in Figure 2-(a), and for incident dose measurement, we used Optically Stimulate Luminescence Dosimeter nanoDot (OSLD; Landauer Co., Glenwood, IL, USA), OSL Microstar Reading System (Laudauer Co., IL, USA) and OSL ANNEALING (Serial No : HA-ONH001, Hanil Nuclear Co., Korea) equipment in Figure 2-(b),(c),(d). In addition, for deep dose measurements, we used a glass dosimeter device (GD-300 series, Asahi Glass co. LTD, Japan), a dosimeter reader (FGD-1000, Asahi Glass co. LTD, Japan), a thermostat (DKN302, yamato co. LTD, Japan), and an electric furnace (New-1C, Hayashi denko, Japan) in Figure 3.

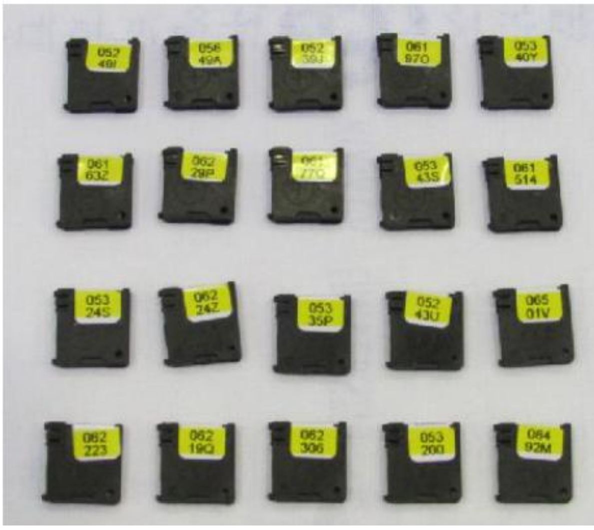


(a) CT Scanner

(b) Rando anthropomophic phantom

Figure 1. Experiment device

(a) Survey Dosimeter



(b) OSL nanoDot

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

(c) OSL Microstar Reading System

(d) OSL Annealing System

Figure 2. Dosimetry and reader system

(a) Glass Dosimeter

(b) Dosimeter Reader

(c) Constant Temperature Oven

(d) Annealing System

Figure 3. The glass dosimetry system

2.2. Research method

To measure the scattered dose except for the target site during the computed tomography, we used a Phantom with a 25 mm slice. The phantom has holes 5 mm in diameter and 30 mm apart on each cross section, and a dosimeter can be placed on the desired site when measuring the dose.

For dose measurement, first, we used a Survey meter to measure space scattering dose, second, to measure incident surface dose, we used OSLD nanoDot, and third, to measure deep dose, we used a glass dosimeter.

The dose measurement experiment was divided into Head test, Chest test, and Abdomen test, which are used most in clinical practice. Head examination included cervical spine 1 at the head vertex, the Chest test included up to two lumbar spines from the vocal cord to both ribs (Costophrenic angle),

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

and Abdomen test was performed with a scan range of up to 20 mm below the pubic symphysis in the upper diaphragm (Diaphragm top). Test conditions were checked using the standard protocol provided by the equipment manufacturer as shown in Table 1.

<Table 1> Examination scan protocol

Parameter	Head		Chest			Abdomen		
	Scout	Pre	Scout	Pre	Post	Scout	Pre	Post
kVp	120	120	120	120	120	120	120	120
mA(s)	30	250	300	103	106	30	100	168
Slice thickness (mm)		5		5	1		5	5
Increment(mm)		10		5	0.5		5	5
Pitch		-		0.609	0.609		1.015	1.015
Rotation time(s)		0.75		0.5	0.5		0.5	0.5
FOV(mm)		240		350	350		350	350
Filter		smooth		Y-sharp	standard		Y-sharp	Y-sharp
Collimation		16x 0.625		64x 0.625	64x 0.625		64x 0.625	64x 0.625
Length(mm)		170		370	370		470	470

The choice of the location for the measurement of radiation dose was based on organs that are susceptible to radiation, namely Orbit for Head, Breast for Chest, and Godnad for Abdomen. The position of the device was referenced in preceding studies [12].

For measurement, we used a meter that received periodic calibration (March 2017), and background values of the dosimeter were recorded through the reading process after the annealing process before the CT scan. In order to reduce the error of the measurement value, the average value was used after 5 times cumulative measurement for each experiment, and then the dose element was read out and the value obtained by subtracting the background value recorded before the experiment was divided by 5. In addition, the average value of three readings was used for the reading.

III. RESULTS AND DISCUSSION

In the head CT scan, at breast, the space dose was 48.2 ± 0.34 μSv, the surface dose was 82.0 ± 2.29 μSv and the deep dose was 376.0 ± 1.58 μSv. In the Gonad, the space dose was 9.7 ± 0.02 μSv, the surface dose was 20.0 ± 1.36 μSv, and the deep dose was 12.0 ± 1.27μSv.

In the chest CT scan, at orbit, the space dose was 229.0 ± 2.85 μSv, the surface dose was 167.0 ± 1.27 μSv and the deep dose was 506.0 ± 1.58 μSv. In the Gonad, the space dose was 72.6 ± 0.41 μSv, the surface dose was 96.9 ± 1.53 μSv, and the deep dose was 190.0 ± 1.58μSv.

In the abdomen CT scan, at orbit, the space dose was 68.7 ± 0.34 μSv, the surface dose was 72.0 ± 1.36 μSv and the deep dose was 224.0 ± 1.58 μSv. In the Breast, the space dose was 145.2 ± 1.57 μSv, the surface dose was 4597.0 ± 1.27 μSv, and the deep dose was 9137.0 ± 1.27μSv as shown in Table 2.

<Table 2> Analysis of the results of radiosensitive organ dose according to examination.

EXAM	ORGAN	DOSE	VALUE (μSv)
Brain CT	Breast	Space Dose	48.2 ± 0.34 μSv
		Surface Dose	82.0 ± 2.29 μSv
		Deep Dose	376.0 ± 1.58 μSv
	Gonad	Space Dose	9.7 ± 0.02 μSv
		Surface Dose	20.0 ± 1.36 μSv
		Deep Dose	12.0 ± 1.27 μSv
Chest CT	Orbit	Space Dose	229.0 ± 2.85 μSv
		Surface Dose	167.0 ± 1.27 μSv
		Deep Dose	506.0 ± 1.58 μSv
	Gonad	Space Dose	72.6 ± 0.41 μSv
		Surface Dose	96.9 ± 1.53 μSv
		Deep Dose	190.0 ± 1.58 μSv
Abdomen CT	Orbit	Space Dose	68.7 ± 0.34 μSv
		Surface Dose	72.0 ± 1.36 μSv
		Deep Dose	224.0 ± 1.58 μSv
	Breast	Space Dose	145.2 ± 1.57 μSv
		Surface Dose	4597.0 ± 1.27 μSv
		Deep Dose	9137.0 ± 1.27 μSv

According to the preceding studies, the reason for big difference in the patient dose was because of different examination methods among the medical institutions [13], and it was confirmed that the development of the apparatus and the speeding up of the examination were factors for increasing the dose of the patient [14]. CT scans are required to maintain an adequate balance between patient benefit and exposure risk because of the high dose received by the patient as compared to other imaging equipment [15]. The physical image quality of the image is generally proportional to the radiation dose, and the decrease in the dose may accompany the deterioration of the image quality [16]. However, this theory sometimes leads to unnecessarily high irradiation conditions or an increase in the patient's exposure dose by scanning a wide range. Therefore, efforts should be made to reduce the dose within the range of maintaining the diagnostic value, taking into consideration the loss due to radiation exposure of the patient rather than increasing the image quality by increasing the radiation dose.

In addition, the susceptibility to radiation depends on the age at the time of exposure. Generally, the more fragile, the more susceptible to radiation because cell division occurs vigorously [17]. Thus, the lower the age, the more need to manage radiation, and the results show that the spatial dose and the scattering dose on the surface are significant. Especially, deep dose was found to increase more by the scattering of the subject. Therefore, we can see that protocol management has a considerable influence on CT examinations for children, pregnant women, and possibly pregnant patients.

IV. CONCLUSION

The proportion of CT in clinical imaging is gradually increasing, and it is expected that the exposures of patients will gradually increase due to the absence of alternative diagnostic imaging equipment despite the risk of exposure. However, the fact that the increase in medical exposures due to the legitimacy of clinical diagnosis should not be overlooked is also the role of radiology doctors and radiotechnologists working at the front lines. It is often the case that the scope of inspection is widened for the sake of the user's convenience, so that the dose index increases and the dose increases. Therefore, it is necessary to be aware of the radiation protection for the organs with sensitive radiation sensitivity in addition to the management of the inspection protocol of the main flux during the CT examination. Especially, when examining young, pregnant women, and possibly pregnant women, it seems necessary to make constant efforts to reduce the dose of radiation by optimizing the radiation protection by blocking the space other than the main flux.

REFERENCES

1. Kim CG. Exposure dose reduction using Pb banding of own manufacturing. Journal of Digital Convergence.2013; 11(6): 269-273.
2. Kim CG. Radiation dose reduction effectiveness of a male gonadal shield during 128-MDCT using Glass Detector. Journal of Digital Convergence.2013; 11(7): 237-242.
3. http://www.mfds.go.kr/index.do
4. Barnes BT, Gould RG, Seibert JA. Specification, Acceptance testing and quality control of diagnostic X-ray imaging equipment. 1994; American Association of Physicists in Medicine. Medical physics monograph, No. 20, 899-936.
5. Korean Food and Drug Administration. Amount of recommended regular medical imaging tests, a patient dose of Guidelines. Radiation safety management series; 2012. No. 30.
6. Korean Food and Drug Administration. Pediatric CT patient dose radiological dose recommendation guidelines for inspection. Radiation Safety Management Series; 2012. No. 31.
7. National Institute of Food and Drug Safety Evaluation. The amount of patient dose recommendations for guidelines on the CT X-ray inspection. Radiation Safety Management Series; 2009. No. 19.
8. Korean Food and Drug Administration. Pediatric CT patient dose radiological dose recommendation guidelines for inspection. Radiation Safety Management Series; 2012. No. 31.
9. Yoon JA. A comparative study on radiation safety management knowledge, attitudes and behavior of career dental hygienists and new dental hygienists. J Dent Hyg Sci.2011; 11(3): 173-9.
10. Sohrabpour M, Hassanzadeh M, Shahriari M. Gamma irradiator dose mapping simulation using the MCNP code and benchmarking with dosimetry. Applied radiation and isotopes. 2002; 57(4): 537-542.
11. Kim YH, Choi JH, Kim SS. Patient exposure doses from medical x-ray examinations in Korea. Journal of radiological science and technology. 2005; 28.
12. Kim KJ, Jung HR, Lim, CH, Hong DH, Shim JG, You IG. A Study on the Mitigation of the Exposure Dose Applying Bolus Tracking in Brain Perfusion CT Scan. Journal of Digital Convergence. 2014; 12(3): 353-358.
13. Hart D, Hillier MC, Wall BF, et al. Doses to Patients from Medical X-ray Examinations in the UK-1995 Review.1996; NRPB-R 289, HMSO, London, UK.
14. Nickoloff EL, Alderson PO. Radiation exposures to patients form CT: Reality, public perception, and policy. AJR. 2001; 177: 285-291.
15. Gang EB, Park CW. The Effects of Reducing a Dose on the Genital Gland at a CT Scan on the Whole Abdomen According to the Shielding Material. Journal of the Korean Society of Radiology. 2016; 10.6: 419-425.
16. Kwon SM, Kim JS. The Evaluation of Eye Dose and Image Quality According to The New Tube Current Modulation and Shielding Techniques in Brain CT. Journal of the Korean Society of Radiology. 2015; 9(5).
17. Korea Food & Drug Administration. Standard diagnostic reference level (DRL) for the pediatric brain CT recommended. Radiation Safety Management Series; 2012. No. 31.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication