Evaluation of Environmental dose in Diagnostic Radiation CT (Computed Tomography) Room

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Abstract

Background/Objectives: CT (Computed Tomography) scanning plays an important role in diagnosis and treatment of patients, and, with the recent development of equipment and scanning techniques, it is commonly used in hospitals. **Methods/Statistical analysis**: By choosing 7 hospitals which perform CT scanning 500 times or over a month, we measured environmental radiation doses in CT room for over one month from November 19 to December 31, 2019. Using glass dosimeter for environmental monitoring, this research measured and analyzed accumulated leakage doses of radiation zones of CT room with preventive wall and shielding efficiency of patient-observing window. The aim of this research was to provide data for planning and education of safety management of diagnostic radiation.

Findings: 1cm dose equivalent values of glass dosimeter for 3 months were 0.78mSv at maximum, and 0.24mSv on average on the door of CT moderating room; 1.35mSv at maximum, and 0.34mSv on average on the shielding wall of CT moderating room; 1.29mSv at maximum, and 0.27mSv on average on the shielding wall in the entrance of CT room. There was no dose exceeding natural radiation on the entrance door of CT room used by patients. The accumulated values of 1cm dose equivalent for three months on the inside of CT room were 117.30mSv at maximum, and 87.07mSv on average, and the accumulated values of 1cm dose equivalent for three months on the outside of CT room were 0.69mSv at maximum, and 0.16mSv on average, proving the shielding efficiency of 99.8% of patient-observing window.

Improvements/Applications: It is necessary to do continuous researches on monitoring of environmental radiation of diagnostic radiation generator in the whole preventive facilities of diagnostic radiation generator as well as CT room, and on defects on window frame and shielding efficiency of radiation shielding bodies.

***Keywords*:** CT, diagnostic radiation, environmental monitoring, safety, shielding

1. Introduction

CT (Computed Tomography) scan plays a very important role in diagnosing and treating patients. In recent years, technological development have led to improvement of its apparatus test techniques, allowing it to be commonly used.[1, 2]. According to Health Insurance Review and Assessment Service, while the number of patients who get CT or MRI scans has continuously increased over the past 5 years, the number of patients who get PET scans has rapidly decreased from 2015. For example, the number of patients under CT scans had increased from 4,118,434 in 2012 to 5,139,149 in 2016, 22% increase (1,020,715), or annual increase of 5.7%. The medical bill spent for CT scan had also increased from 832.8 billion to 1,047.1 billion won over the same period of time, 25.7% increase (214,3 billion won), or annual increase of 5.7%.[1,2].

To provide patients with proper treatment, and protect patients and those working in radiology from damage of radiology, it is necessary to safely manage diagnostic radiation apparatus. So, the Ministry of Health and Welfare established the Rules on Diagnostic Radiation Safety Management.[3] . According to the rules, 'radiation zone' is the area where exterior radiation amount is 0.3mSv (30mrem) or over per week from the site where diagnostic radiation unit is placed, and which is compartmentalized with walls or protective partitions[4,5].

According to the criteria on prevention facilities against radiation stipulated in Clause 2 of Article 37 of Medical Law, the founder or manager of medical institution should get inspection from inspection agency on diagnostic radiation generator before using it. Plus, if the institution wants to change installation of the radiation shielding facilities in radiation prevention facilities, or design shielding facilities, it should get inspection of prevention facilities from the inspection agency if the radiation amount the scanner generates exceeds the maximum operating load per week allowed[6-10].

The criteria on preventive facilities of radiographic room where diagnostic radiation generator is installed and used are that shielding facilities (hereafter will be called "shielding wall") which cannot be moved or removed without tools should be built on the ceiling, wall, and floor, and that total radiation leakage dose and scattering dose measured outside of the radiographic room should be 2.58×C/kg (100mR per week) or less. But, shielding wall need not be installed to the direction where man does not pass or stay, and total radiation leakage dose and scattering dose measured outside of the radiographic room to the direction where man unrelated with radiology should be 2.58×C/kg per week (100mR per week) or less[3].

The criteria of inspection for diagnostic radiation prevention facilities in Korea require that the institution should get inspection when it installs the radiation equipment, when the maximum operating load per week exceeds the allowed amount, or when it changes shielding facilities. Such a legal advice lacks clear criteria on the kind of shielding materials, kind of diagnostic radiation generator, and other conditions. The criteria on leakage dose do not match international dose, and it does not designate criteria on periodic safety management. Thus, it is difficult to trust radiation preventive facilities in Korea. Therefore, it is necessary to do periodic and credible safety management of the test room using radiation generating equipment and prepare criteria on it.

Glass dosimeter uses the principle that, if radiation is projected to glass element coated with Ag^{+}, defect of atomic structure ionized into Ag^{++}, Ag^{o} is generated, and laser is injected, it generates orange color light depending on the degree of exposure to radiation. Glass dosimeter has a wide measurement range of 10μGy -10Gy, and small dependence on dose rate, and has very small fading of fluorescent amount. And, it is very excellent in repeated use, reproducibility and accuracy[11-15].

Due to such characteristics of glass dosimeter, it is frequently used in monitoring of medical diagnostic radiation, medical treatment radiation, and environmental radiation. Accordingly, this research, using glass dosimeter for environmental monitoring, measured dose distribution of CT room, accumulated doses for 3 months of window to observe patients and dose after shielding, and compared them with corresponding data of foreign countries. The aim of this research is to use the findings for planning safety management of diagnostic radiation and for basic data for education.

2. Research objects and method

2.1. *Evaluation of border environment dose of radiation zone of CT room*

The CT scanners this research used to measure environmental doses around shielding walls of CT room are SOMATOM Definition AS (Siemens, Germany) CT scanner which can get 128 slice images with one rotation [Fig. 1].

By choosing 7 hospitals which perform CT scanning 500 times or over a month, we measured environmental radiation doses in CT room for over one month from November 19 to December 31, 2019. To measure environmental radiation, we used Glassbadge (GB) RS type made by Chiyoda Technology Measurement Management Center (千代田テクノル), Japan.

Glass dosimeter is measurement device most suitable for environmental measurement for a long period because of its high precision, reproducibility, and linearity, and low energy dependency. In Korea, there is no legal standard based on accumulated doses over long period about the facilities using diagnostic radiation generator. Accordingly, we procured the glass dosimeter from Chiyoda Technology in Japan acknowledged in the world, measured doses for one month, and sent the glass dosimeter to Radiation Measurement Center in Japan to read it [Fig. 2].

Figure 1. CT scanner

Figure 2. Glass dosimeter to measure environmental radiation

2.2. *Installation of glass dosimeter to measure environmental radiation around radiation zone of CT room and patient-observing window*

The location to place the glass dosimeter measuring environmental radiation was around the radiation zone of the room. The locations to measure radiation were shielding wall of the door of CT room patients use, the door patients use, the door of moderating room, and the patient-observing window. The devices were placed 150 - 170cm over the ground considering the location of the CT scanner.

To measure and evaluate shielding efficiency of patient-observing window, glass dosimeters were placed inside and outside of the CT room for one month. We sent the glass dosimeters to Chiyoda Technology and received the measurement results from the company. To compare the results with the criteria on environmental radiation in Japan, we used the tripled values of our results.

2.3. *Statistical treatment and analysis*

To analyze the data, we used SPSSWIN (Ver 22.0) program. To test significance in differences of dose values in experimental group and control group, we did t test. The significance levels of all statistics were set at $p<0.05$.

3. Research findings and discussion

3.1. *The findings of measurement of environmental dose around the radiation zone of CT room*

In Korea, medical institutions are required to radiation "preventive wall" which cannot be moved or eradicated without using tools on ceiling, floor, and wall of the place where diagnostic radiation generator is installed and used. And, the sum of leakage and scattered doses measured in the opposite sides of preventive wall should be 2.58×C/kg (100mR per week) or less. Based on such requirements, most medical centers measure instant leakage dose with dosimeter, and convert it to its accumulated dose considering the operating time of the scanner.

To manage diagnostic radiation dose in Korea, the medical law requires medical centers to measure doses before the radiation generator is used after it is installed, when the shielding facility is changed, and the dose exceeds the maximum operating load per week. Such a management method does not consider the fact that environmental accumulated dose of diagnostic radiation differs depending on strength of radiation energy, and operating time.

For such a reason, the Japanese government sets the safety standards on environmental monitoring of diagnostic radiation based on accumulated dose for a certain period.

According to a report in 2019 of Korean Center for Disease Control (KCDC), the annual average exposure dose of workers related with radiation in Korea is 0.45mSv, while that in Japan is 0.30mSv. It seems to be related with legal requirement on environmental monitoring of diagnostic radiation in Korea. This research suggests that Korea also adopts the monitoring values of accumulated dose over a long period in radiation preventive facilities for safety management.

This research attached glass dosimeter 170-190cm over the ground in CT rooms where CT scanning is done 500 times or over a year, and dose was measured for one month, and the values were tripled to compare them with those of Japanese standards where 1cm dose is 1.32mSv.

Table 1. Doses around the radiation zone of CT room

Hospital	Door of moderating room	Wall of moderating room	Entrance door	Entrance wall
1	-	0.33	-	0.30
2	-	-	-	0.27
3	**0.54**	**1.35**	**-**	**1.29**
4	-	0.18	-	-
5	0.18	0.15	-	-
6	**0.78**	0.15	-	-
7	0.21	0.21	-	-
Average	0.24	0.34	-	0.27

By measuring accumulated doses with glass dosimeters on the door of CT moderating room, the wall of CT moderating room, the door of CT room, and the shielding wall of entrance of CT room, we got the values as shown in Table 1. The accumulated values of 1cm dose equivalent for three months on the door of CT moderating room were 0.78mSv at maximum, and 0.24mSv on average, which satisfied the requirement of the Japanese standards.

The accumulated values of 1cm dose for three months on the shielding wall of CT moderating room were 1.35mSv at maximum, and 0.34mSv on average, which means that one hospital violated the requirement of the Japanese standards. There was no dose exceeding natural radiation on the entrance door of CT room used by patients.

The accumulated values of 1cm dose equivalent for three months on the shielding wall in the entrance of CT room were 1.29mSv at maximum, and 0.27mSv on average, which satisfied the requirement of the Japanese standards[Table 1].

Thus, The cases whose radiation doses violated the Japanese standards or were close to violation of the standards seem to be caused by either defective construction or deterioration or increase of fatigue of concrete or other materials in shielding walls.

It is necessary to minimize exposure dose of radiation of visitors, patients, patient protectors, and care-givers as well as those working in the radiation part as much as possible. The findings seem to show the evidence that dose management in Korean hospitals using diagnostic radiation should be done based accumulated dose of environmental doses as Japanese hospitals do.

3.2. *Dose analysis of patient-observing window of CT room*

If the shielding material of preventive wall is lead plate, it should satisfy the following requirements.

A) The material should not be folded or curved by its own weight, and it should not get direct physical impact.

B) The part where lead plates are connected should be covered with lead plate with the width of 1.5cm or more, and the part where lead plate and other shielding material should be covered with lead plate with the width of 2.5cm or more.

The floor area of the control place whose control equipment is not attached to X-ray high voltage generator should be 1.5 ㎡ or more, and the distance between shielding wall and test table should be at least 2m, and, considering the highest tube voltage of diagnostic radiation generator, the structure of preventive wall and patient-observing window should be the followings.

A) If the highest tube voltage exceeds 100KV,

- preventive wall should be 1.5mm or over lead equivalent,
- patient-observing window should not be loaded with 100KV lead equivalent.

B) If the highest tube voltage is 100KV or less,

- preventive wall should be 1.0mm or over lead equivalent, and the size should be 1m×2m or bigger,
- patient-observing window should be 1.0mm or over lead equivalent.

As the highest tube voltage used in CT room exceeds 100KV, preventive wall and patient-observing window should be 1.5mm or over lead equivalent. Thus, all the medical institutions using CT radiation generator should be equipped with preventive wall and patient-observing window of 1.5mm or over lead equivalent.

This research tested shielding functions of inside and outside of patient-observing window used in CT room, and measured and analyzed environmental radiation of diagnostic radiation generator to use the data as the basis of safety management.

The accumulated values of 1cm dose equivalent for three months on the inside of CT room were 117.30mSv at maximum, and 87.07mSv on average, and the accumulated values of 1cm dose equivalent for three months on the outside of CT room were 0.69mSv at maximum, and 0.16mSv on average, proving the shielding efficiency of 99.8% of patient-observing window[Table 2].

The above experiments showed different values in environmental radiation amounts of inside the patient-observing window, depending on energy used for CT scanning and the frequency of using the scanner. The reason for the difference in shielding efficiency seems to be caused by decrease of shielding efficiency with the increase of fatigue of materials and defective window frame.

This research has limits in the sense that measurement was done in medical institutions in a specific region because of the non-cooperation of medical institutions for one-month measurement of accumulated doses of environmental radiation, worries about measurement findings, and the difficulty of managing glass dosimeter, etc. In the future researches, it seems necessary to do continuous researches on the whole preventive facilities on diagnostic radiation in addition to CT room, defects of window frames, and shielding efficiency caused by long-term use of them.

Table 2. Doses of patient-observing window in CT room

Hospital	Inside of the window	Outside of the window	Shielding rate(%)
1	110.20	0.24	99.8

2	13.3	-	100
3	84.60	-	100
4	88.50	-	100
5	117.30	0.69	99.4
6	108.00	0.18	99.8
7	87.60	-	100
Average	87.07	0.16	99.8

4. Conclusion

This research measured and analyzed accumulated leakage dose of radiation zone where preventive walls in CT room and shielding efficiency of patient-observing window. The accumulated values of glass dosimeter of 1cm dose for three months were as follows: 0.78mSv at maximum and 0.24mSv on average on the door of CT moderating room; 1.35mSv at maximum, and 0.34mSv on average on the shielding wall of CT moderating room. There was no additional dose value over natural radiation on the entrance door of CT room.

The accumulated values of glass dosimeter of 1cm dose for three months on the inside of CT room were 117.30mSv at maximum, and 87.07mSv on average, and corresponding values on the outside of CT room were 0.69mSv at maximum, and 0.16mSv on average, proving the shielding efficiency of 99.8% of patient-observing window.

It is expected that the findings of this research will be good source in doing safety management on diagnostic radiation. This research suggests doing continuous researches on the whole preventive facilities on diagnostic radiation in addition to CT room, defects of window frames, and shielding efficiency caused by long-term use of them.

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