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High-Energy Electromagnetic Wave Radiation Analysis Study of Laboratories Using Digital Medical Imaging Devices

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Devices that acquire digital medical images using radiation (DR; Digital Radiography) are widely used in medical institutions to obtain information necessary for patient diagnosis, and the frequency of use is gradually increasing. By selecting 3 hospitals that perform more than 50 digital X-ray medical imaging tests per day, and by installing a glass dosimeter for environmental measurement on the outside of the examination room protection wall, entrance door, and patient viewing window, the leakage radiation dose was measured for one month from May 16, 2021 to June 21, 2021, then it was analyzed by converting into a 3-month cumulative dose. The cumulative dose equivalent of 1 cm in the glass dosimeter for 3 months outside the shielding wall at the entrance of the digital medical image acquisition radiation generating device examination room was 0.96 mSv, and the average value was 0.18 mSv. In addition, the cumulative 1 cm dose equivalent value of the glass dosimeter for 3 months outside the shielding wall on the control room side showed a maximum of 3.03 mSv and an average of 0.41 mSv. The glass dosimeter cumulative dose 1cm dose equivalent value was up to 8.31 mSv and averaged 2.09 mSv for 3 months outside the door of the patient waiting room of the digital medical image acquisition radiation generating device examination room. In addition, the glass dosimeter cumulative dose 1cm dose equivalent value for 3 months outside the control room door showed a maximum of 14.04 mSv and an average of 3.84 mSv. These research results are expected to be widely used in setting measurement methods and regulatory standards for environmental radiation safety management of medical radiation generators, and continuous research management at the national level is suggested.

Keywords : digital medical imaging device, electromagnetic wave, glass dosimeter, safety management, shielding wall

1. Introduction

Devices that acquire digital medical images using radiation (DR; Digital Radiography) are widely used in medical institutions to obtain information necessary for patient diagnosis. Compared to the existing film-sensitization method and computerized radiography system (CR, computed radiography system) method, digital medical imaging radiation generator has advantages such as image processing speed, diverse image parameters, image quality improvement through utilization, wide dynamic range, image post-processing method to remove noise from output instability, and artifact correction [1-3].

For this reason, the frequency of use of digital medical imaging radiation generators is gradually increasing [4, 5]. The number of annual diagnostic medical radiological examinations among people in Korea increased from about 312 million in 2016 to about 374 million in 2019, an annual average increase of about 6.2 %, and in 2019, there was an increase of about 20 % compared to 2016 [6-9].

The average number of annual medical radiation examinations per person in Korea increased from 6.1 in 2016 to 7.2 in 2019, and the exposure dose increased from 1.96 mSv in 2016 to 2.42 mSv in 2019, which is high compared to the United States and Europe.

The per capita exposure dose overseas is 1.88 mSv in the United States (2016) and 0.97 mSv (0.25 mSv-1.96 mSv) in 36 countries in the European Union (2014) with Belgium 1.96 mSv, Germany 1.67 mSv, Finland 0.45 mSv, and UK 0.39 mSv.

Radiation shielding walls must be installed on the ceiling, floor and walls for radiation protection facilities of facilities using radiation generators that acquire digital

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medical images, and the sum of the radiation leakage dose and the scattered dose measured from the outside of the shielding wall need to be kept below 100 mR per week. However, it is not necessary to install a shielding wall in the direction where people do not pass or reside, and it is stipulated that the sum of the radiation leakage dose and the scattered dose measured from the outside of the shielding wall installed in the direction in which a person other than the radiation person resides should be less than 10 mR per week.

In Korea, in order to comply with these regulations, the protection facility inspection is performed by measuring the radiation dose when the digital medical imaging radiation generator is first installed and when the shielding facility is changed. In Japan, every 6 months, glass dosimeters are installed in digital medical imaging radiation generator inspection facilities, and by measuring the cumulative dose of leaked radiation for one month, medical radiation safety management is carried out in accordance with the Medical Radiation Safety Management Standard Act.

There is a difference in the annual exposure dose of radiation workers due to different safety management methods in each country [10, 11]. The annual exposure dose is 0.45 mSv in Korea, 0.32 mSv in Japan, and 0.06 mSv in Canada. In order to reduce the exposure dose of medical radiation workers, patients, and patient caregivers in Korea, it is necessary to find a new medical radiation safety management method and to develop a measurement technology suitable for the Korean environment [12-15].

Therefore, this study was conducted to measure the 3-month cumulative dose of the radiation protection facility shielding wall of the radiation generating device that acquires digital medical images using a glass dosimeter for environmental monitoring, and to improve the diagnostic radiation safety management method by comparing it with foreign standards and to present it as basic data for education.

2. Subjects and Methods

2.1. Digital Medical Image Acquisition Radiation Generator Examination Room Shielding Wall Leakage Dose Assessment

In this study, DK medical system Innovision (Ceiling Type - ELIN T5) was used to measure the radiation dose of the digital medical imaging radiation generator examination room protection wall (Fig. 1). Innovision device is a device that can quickly check a clear image with a low radiation dose and can be used easily and safely. This device is widely used as a device that supports conversion of standard medical images.

Fig. 1. (Color online) Digital medical imaging device for measuring leakage dose in high-energy electromagnetic waves.

By selecting 3 hospitals that perform more than 50 digital X-ray medical imaging tests per day, a glass dosimeter for environmental measurement was installed outside the protection wall of the examination room, and the leakage radiation dose was measured for one month from May 16 to June 21, 2021.

As the environmental leakage radiation measuring device, a glass dosimeter (Glassbadge: GB) RS of Chiyoda Technol Corporation of Japan suitable for medical X-ray measurement was used, and diagnostic radiation environmental radiation measurement location was measured by installing it at 150-170 cm from the floor considering the location of the radiation generator (Fig. 2).

In order to secure the reliability of the measured data, the dosimeter collected after measuring the accumulated environmental leakage dose was requested to the mea-

Fig. 2. (Color online) Glass dosimeter installation location for high-energy electromagnetic wave measurement.

surement management center of Chiyoda Technol in Japan, and the glass dosimeter was read.

2.2. Digital Medical Image Acquisition Radiation Generator Examination Room Entrance and Patient Viewing Window Glass Dosimeter Installation and Dose Analysis

The safety of radiation workers and the general public was evaluated and analyzed by measuring the leakage dose from the digital medical image acquisition radiation generator examination room entrance and patient viewing window.

The glass dosimeter was installed at 150-190 cm from the floor considering the safety of the patient entrance and exit door, the entrance door of the digital medical image acquisition radiation generator control room, the shielding wall, and the patient viewing window based on the medical image X-ray examination room (Fig. 3).

To measure and evaluate the shielding efficiency of the patient viewing window, multiple glass dosimeters were installed inside and outside the laboratory to measure environmental radiation dose and verify statistical significance. The dosimeter recovered after measurement was delivered by air to Chiyoda Technol, Japan, without the procedure of passing the X-ray screening station, and the results were analyzed. By multiplying the measurement result by a factor of 3, a comparative analysis was performed with the Japanese medical radiation safety management standard.

2.3. Statistical Processing and Analysis

The data analysis was performed using the SPSSWIN (Ver 22.0) statistical program, and the t-test was performed to verify the significance of the average value of the exposure dose measurements of the control group and the experimental group. The significance level of all statistics was set to $p<0.05$.

Fig. 3. (Color online) Glass dosimeter installation location for lead glass leakage dose measurement.

3. Results and Discussion

3.1. Digital Medical Image Acquisition Radiation Generator Examination Room Shielding Wall Leakage Dose Evaluation Result

In Korea, a radiation “shielding wall” that can shield leakage and scattered dose must be installed on the wall of the examination room where a digital medical image acquisition radiation generator is installed to conduct an examination for the purpose of diagnosis. The total radiation measured from the outside should be less than 100mR per week for the shielding facility standard of the shielding wall for leakage dose and scattered dose.

In Korea, the safety management of the shielding wall of the laboratory using the radiation generator for digital medical image acquisition is measured and managed by measuring the dose before the start of use or when the radiation shielding facility is changed.

In the case of Japan, after the Fukushima nuclear accident in 2011, medical radiation safety management has been changed from radiation dose-based to absorbed dose-based management. As a result of these results, as of 2019, the average annual exposure dose of radiation-related workers is maintained at 0.30 mSv. In the case of Korea, it is 0.45 mSv as of 2019.

In this experiment, 10 examination rooms for digital medical image acquisition in hospitals that have passed the “shielding wall” standard for medical radiation safety management in Korea were selected, installed with an environment glass dosimeter, and the accumulated dose for one month was measured and analyzed.

The installation location of the environmental glass dosimeter was attached at a height of 170-190 cm from the floor, where leakage and scattered radiation frequently occur, based on the legal standards for installing a protection wall. The environmental glass dosimeter dose analysis was compared and analyzed with the Japanese standard of 1 cm dose equivalent by multiplying the measured one-month cumulative dose by 3 times.

Table 1 shows the results of measuring the accumulated dose for 3 months by installing a glass dosimeter on the shielding wall of the control room side of the digital medical image acquisition device, which is the boundary of the radiation area, and the shielding wall of the entrance.

The cumulative dose of 1 cm of glass dosimeter for 3 months outside the shielding wall at the entrance of the

Table 1. Digital medical image radiation generator examination room shielding wall dose analysis result.

Examination Room	Entrance Shielding Wall	Control Room Shielding Wall
1	-	-
2	-	0.24
3	0.96	-
4	0.57	-
5	-	3.03
6	-	0.33
7	-	0.30
8	-	0.18
9	0.30	-
10	-	-
Average	0.18	0.41

digital medical image acquisition radiation generator examination room showed a maximum of 0.96 mSv and an average of 0.18 mSv. In all 10 examination rooms where the examination was conducted, the result value was below the Japanese standard value. The cumulative dose of 1 cm of the glass dosimeter for 3 months outside the shielding wall on the side of the control room of the digital medical image acquisition radiation generator laboratory showed a maximum of 3.03 mSv and an average of 0.41 mSv.

In the 10 examination rooms where the examination was conducted, 1 examination room measured above the Japanese standard value, and in 9 examination rooms, the result value was below the Japanese standard value.

In the result where the cumulative dose of 1 cm of the glass dosimeter for 3 months outside the shielding wall of the digital medical image acquisition radiation generating device control room exceeded the Japanese safety management leakage dose standard, it is judged that partial poor construction was performed when the shielding wall was first installed, or the deterioration or fatigue of the concrete, building materials, and shielding material of the shielding wall was increased.

If the dose outside the digital medical image acquisition radiation generator examination room control room's shielding wall exceeds the safety management standard value, the radiation dose of radiation-related workers in medical institutions increases. These results can act as a cause for the increase in occupational exposure of radiation-related workers, lowering their motivation to work, and impairing the improvement of public health and welfare.

As the result of the analysis above, this is not a problem in Korea's safety management standards, but in Japan's safety management standards, a shielding wall in the control room side of the digital medical image acquisition radiation generator that exceeds the dose was confirmed.

According to these results, it is judged that the insufficient parts of safety management standards and management methods in Korea can be supplemented by using Japanese safety management standards and management methods, and the exposure dose of radiation workers can be minimized.

3.2. Digital Medical Image Acquisition Radiation Generator Examination Room Entrance and Patient Viewing Window Glass Dosimeter Installation and Dose Analysis

In the case of digital medical image acquisition radiation generator examination room, the maximum tube voltage used exceeds 100 kV, so the shielding wall and patient viewing window must be at least 1.5 mm lead equivalent in Korea's medical radiation safety management standards. Therefore, all medical institutions that use a digital medical image acquisition radiation generator must install a shielding wall and a patient viewing window of at least 1.5 mm lead equivalent.

In this paper, to verify the shielding performance of the patient viewing window used in the digital medical image acquisition radiation generator shielding wall and to use it as the basis for safety management, the cumulative dose of radiation leakage dose after shielding the patient viewing window was measured and analyzed.

The dose equivalent of 1 cm of accumulated dose of glass dosimeter for 3 months outside the digital medical image acquisition radiation generator examination room patient viewing window was measured to be less than or equal to the natural radiation dose in 10 examination rooms where the tests were conducted. These results show that the shielding performance of the digital medical image acquisition radiation generator examination room patient viewing windows of the measured medical institutions meet the medical radiation safety management standards of Korea and Japan.

At the outside of the digital medical image acquisition radiation generator examination room patient waiting room door, the glass dosimeter's cumulative dose of 1 cm for 3 months showed a maximum of 8.31 mSv and an average of 2.09 mSv. Among the 10 examination rooms where the examination was conducted, 4 examination rooms exceeded the Japanese safety management standard dose value, and 6 examination rooms showed the result value below the Japanese safety management standard value.

At the outside of the digital medical image acquisition

Table 2. Digital medical image radiation generator examination room entrance and patient viewing window leakage dose analysis result.

Examination Room	Patient Waiting Room Entrance	Control Room Entrance	Patient Viewing Window
1	0.21	2.13	-
2	0.15	0.90	-
3	0.24	1.20	-
4	5.31	-	-
5	-	3.60	-
6	8.31	4.56	-
7	3.09	1.53	-
8	-	7.11	-
9	0.27	3.33	-
10	3.30	14.04	-
Average	2.09	3.84	-

radiation generator examination room control room door, the cumulative dose equivalent of 1 cm in the glass dosimeter for 3 months showed a maximum of 14.04 mSv and an average of 3.84 mSv. Among the 10 examination rooms where the examination was conducted, 7 examination rooms exceeded the Japanese safety management standard dose value, and 3 examination rooms showed the result value below the Japanese safety management standard value (Table 2).

For the reason that the cumulative dose of leakage dose measured from the outside of the entrance of the digital medical image acquisition radiation generator examination room patient waiting room exceeded the Japanese safety management standard dose value, it was analyzed that it was caused by the energy used in the diagnostic test, the amount of operation per week, and the opening of the door. In particular, if the leakage dose exceeds the safety management standard in the patient waiting room, caution is required because the radiation exposure dose to the general public, such as patient caregivers, may increase.

It was confirmed that the main reason that the cumulative dose of leakage measured from the outside of the digital medical image acquisition radiation generator examination room control room entrance exceeded the Japanese safety management standard dose value was because the test was conducted with the door open. Particular attention is required because there is a possibility that workers in 2 examination rooms out of 10 examination rooms where the examination was conducted may be exposed to a dose exceeding 20 mSv, which is the dose limit for radiation-related workers for one year.

This study has limitations in objectifying the research results because 10 hospitals nationwide were selected through convenience of cooperation. However, it can be said that it is of great significance in confirming the actual status of medical radiation safety management in medical institutions.

Seeing from the result of this study, it is necessary to establish legal safety standards and safety management based on absorbed dose measurement based on long-term cumulative dose measurement and analysis rather than radiation dose measurement based on legal dose management for diagnostic radiation environmental monitoring in Korea. In addition, it is suggested that continuous research on the shielding wall performance of diagnostic radiation shielding facilities be expanded to all medical institutions distributed throughout the country.

4. Conclusions

Using a glass dosimeter, the cumulative leakage dose from the shielding wall, entrance, and patient viewing window of the digital medical image acquisition radiation generator examination room was measured and analyzed for 3 months.

The 1 cm dose equivalent value of the glass dosimeter accumulated for 3 months was 0.96 mSv at the maximum and 0.18 mSv on average at the outer side of the shielding wall at the entrance of the digital medical image acquisition radiation generator examination room. In addition, the cumulative dose equivalent of 1 cm in the glass dosimeter for 3 months outside the shielding wall on the control room showed a maximum of 3.03 mSv and an average of 0.41 mSv.

At the outside of the entrance to the patient waiting room for the digital medical image acquisition radiation generator examination room, the glass dosimeter accumulated dose equivalent of 1 cm for 3 months was maximum of 8.31 mSv and average of 2.09 mSv. Also, outside the entrance to the control room, in 3 months, the cumulative dose equivalent of 1 cm in the glass dosimeter showed a maximum of 14.04 mSv and an average of 3.84 mSv.

It is expected that these research results can be used as basic data for conducting medical radiation safety management in the future. In addition, it is expected that it will be greatly useful in setting measurement methods and regulatory standards for environmental radiation safety management of medical radiation generators.

It is proposed to continue research at the national level by expanding to all medical institutions distributed throughout the country on the shielding wall performance of diagnostic radiation shielding facilities.

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References

[1] Y. H. Seoung, J. K. Radiol. **13**, 749 (2019).
[2] S. Y. Lee, J. Han, and D. C. Kweon, J. Magn. **24**, 303 (2019).
[3] J. W. Kim, W. S. Park, H. S. Kim, S. C. Kim, Y. H. Kang, T. K. Kim, D. K. Han, and Y. C. Heo, J. Magn. **23**, 570 (2018).
[4] W. S. Yang, J. H. Choi, W. J. Shin, and B. I. Min, J. Cont. **11**, 765 (2013).
[5] I. C. Im, J. S. Lee, and D. C. Kweon, J. Radiol. **3**, 155 (2011).
[6] C. S. Jeong and J. Y. Kim, J. Radiol. **7**, 433 (2015).
[7] C. G. Kim, J. Magn. **25**, 644 (2020).
[8] C. G. Kim, J. Medico. **20**, 1887 (2020).
[9] C. G. Kim, J. Psy. Rehabil. **24**, 7 (2020).
[10] Y. Lee, M. H. Choi, H. J. Goh, and D. K. Han, J. Magn. **21**, 281 (2016).
[11] M. S. Cho, J. H. Cho, Y. M. Chang, Y. H. Cho, S. K. Zeon, K. R. Dong, W. K. Chung, H. K. Lee, H. J. Kim, J. Y. Bae, J. O. Ahn, and S. J. Lee, J. Magn. **16**, 350 (2011).
[12] B. S. Kang and C. S. Lim, J. Academia. **11**, 2118 (2010).
[13] Y. S. Han, S. C. Lee, D. Y. Lee, J. W. Choi, J. W. Lee, and D. C. Kweon, J. Magn. **21**, 115 (2016).
[14] C. W. Park and P. K. Cho, J. K. Radiol. **13**, 399 (2019).
[15] J. H. Thrall, Radiol. **279**, 660 (2016).