Quality assurance of ^{137}Cs Photons for Vivo Mouse Irradiation System

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1. Introduction

Biological effects of acute high-dose radiation are well known but the chronic effects of low-dose radiation are yet unclear. In many countries, the mouse irradiation experiment of correlation of the biological effects of chronic low-dose radiation is actively performed. The multi-purpose irradiation apparatus using a ^{137}Cs, which can be used for the blood test, can be affected by the other components of the experiments such as the size and shape of the beaker and the maximum variation of more than 35% has been reported [1].

The mount of the absorbed dose is determined by the distance between irradiation target and the source and the irradiation time with the irradiator (Gamma Irradiator, Chiyoda Technol Co, Japan) for this experiment. The low-dose irradiation has been used in this study is advantageous for irradiating the cell culture vessel or the small animal. However, radiation is performed by placing the 3-5 mice in each mouse cage (polycarbonate cage). In this case, overlapping often happens to the target during irradiation. Irradiating without considering the geometrical aspect of the irradiation device can occur as well. To solve the problems, the mouse apartment with the 45 mouse cages is built and the device is assessed by being compared with the conventional method in 2 different ways. Firstly, the glass dosimeters [2-5] were inserted into the head and the body of the lab mice for 2 methods. Secondly, MCNP simulation was performed for absorbed dose and air kerma measurements in each mouse apartment chamber.

2. Methods

2.1 Radiation generator(gamma irradiator)

The direction and magnitude of the beam was determined by the pyramid-shape beam collimator, and the horizontal angle was 60° from the beam central axis, and the vertical angle was 20° and 40°. The dose can be changed from tens of mGy / h to μGy / h according to the experimental subject by the distance from the radiation source and its intensity. In this study, ^{137}Cs radiation source of 370 GBq (10 Ci) of the cylindrical shape with the 1.27 cm in diameter and 1.91 cm height, and irradiating 0.1 Gy from 2 m distance for 15 hours 11 minutes 58 seconds.

2.2 A Shelf of irradiation apparatus (Mouse cage & apartment)

Mouse cages were made of 120W × 120L × 130H mm using the Acrylic resin material. Unlike the conventional cages, the customized cage consists of the cage box for mouse breeding, the holding plate, the angle adjustable plate, and the distance adjustable plate.

The aluminum profile was used to produce the double structure external support for cage installation, angle and distance adjustments. It is designed to have the external support 1 with 1560W × 550L × 1400H mm in size containing 5th floor shelves, and 9 cages were installed in each floor. The external support 2 had the size of 1650W × 600L × 1900H mm, and the pipe coupling connected jack screw was on the upper deck to balance the apartment and the Ball bosch is installed in the lower deck to support the load and the wheels for mobility [Fig. 1.].

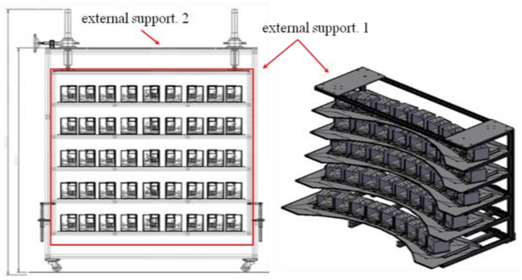
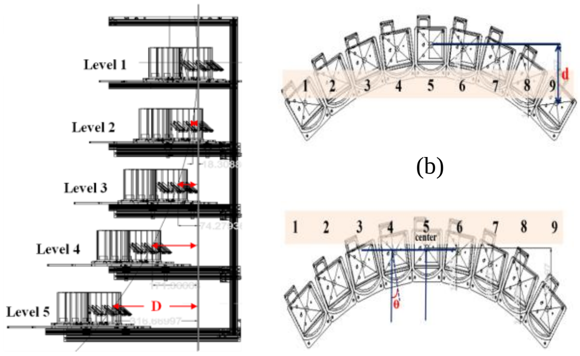


Fig. 1. Mouse apartment manufactured by of dual structure

2.3 Calculation of Angle and Range

A radiation irradiation apparatus, by changing the distance of the apartment of the mice were measured angle and the moving distance of the mouse cage. Distance of the mouse apartment and radiation irradiation device is set to 5 m and, 4 m 1 m, 2 m, 3 m, research angle distance, The mouse cage distance(d) and angle(θ) calculation according to the irradiation angle and the distance between the irradiator and the cage (D'). Fig. 2a is show the location of each level adjustment mouse apartment, was calculated distance of Irradiation Apparatus and radiation irradiation apparatus of the distance, which is slide in each level for each. Sliding distance shelf (D), is calculated based on the center of the floor of the cage of the mouse in a 5 level, depending on the rack position calculated position and angle of the mouse cage was calculated. For location, and calculates the length between the parallel line segment that passes through a parallel line passing through the center point of each level number 5 cage, the center points of the housing case on the same floor (d) [fig. 2b], which if the angle for segment connecting the center points of the mouse cage investigators central point in the center of the investigators of the radiation irradiation device, when the direction of the mouse cages each of which is perpendicular, mice each cage in response to the irradiation angle was calculated the angle [fig. 2c].



(a) (c)

Fig. 2. Calculate the position of at a fixed distance from the radiation source center. (a) Adjustment of the distance of each level with mouse apartment. (b), (c) Adjustment of the angle and distance of the mouse cage in accordance with the irradiation.

2.4 Experimental animals

The 7 weeks old male and female BALB/c mice (central laboratory animals, Seoul) were used for the experiments. The experiments were performed under the condition of 23 ± 2 ℃ in temperature, 50 ± 5% in relative humidity, 12 hours of lighting time (8 am lighting - 8:00 pm off), 13-18 air circulation per day, and 200~300 lux illumination. The feed for mice (central laboratory animals, Seoul) and water through the pipe after purification were offered to the mice. All animal experiments had been conducted under the accordance with Guide for the Care and Use of Laboratory Animal of the Institute of Laboratory Animal Resource in (1996, USA), after gained the permission from the Dongnam Institute of Radiological and Medical Sciences Institutional Animal Care and Use Committee.

2.5 Measurement of radiation dose

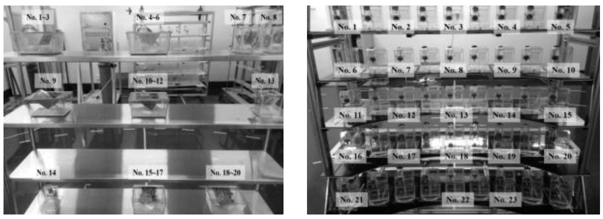
Glass dosimeter (GD-302M, Asahi Techno Glass Corporation, Shizuoka, Japan) used in the experiment had the characteristics of the dose measurement range of 10 μGy~500 Gy, and has less than 3% energy dependency and less than 5% angle dependency [6]. The FGD-1000 reader (Asahi Techno Glass Corporation, Shizuoka, Japan) was used to read the glass dosimeter. The measurement range of the low-dose magazine used at the time of reading is 10 μGy~10 Gy and that of the high-dose magazine is 500 Gy. In this study, for the reading of the glass dosimeter dose value from the ^{137}Cs radiation source, the calibration factor of the glass dosimeter was determined by comparison with the ionization chamber reading at the same position. Then, the glass dosimeter reading value was converted into the absorbed dose value by applying the calibration factor to the reading value.

2.6 Comparison between two method

To quantitative assessment of the newly developed mouse apartment, the absorbed doses from the conventional irradiation method [fig. 3a] and newly developed system [fig. 3b] were compared. The arbitrary numbers from 1 to 20 and 1 to 23 were granted to the mice for the conventional method and the mouse apartment respectively.

In fig. 3a, No.1-3, 4-6, 10-12, 15-17, and 18-20 were in each conventional cage and No 7, 8, 13, and 14 were in the new cages separately so that identify the effects by overlapping between mice. Additionally, No. 9 was in the conventional cage so that the effects between different cages.

In fig. 3b, the mice were located in each chamber in the mouse apartment at the distance of 2 m from the radiation source and the angle and the position of each chamber were determined according to the distance calculation.



(a) (b)

Fig. 3. Mice were placed in a cage on shelves located 2 m from the source representing 0.1 Gy exposure. (a) Absorbed dose measurement from conventional irradiation method. (b) Absorbed dose measurement from newly developed system

3. Result

The average absorbed dose in mice was 0.0961 Gy at 4th floor (No. 1-8), 0.0972 Gy at 3rd floor (No. 9-13) and 0.066 Gy 1st floor (No. 14-20). The variances from different floors was significant, especially significantly less dose was irradiated to the mice in the 1st floor.

Specifically, the difference between the head and body absorbed dose in a single suite (No. 7, 8, 13, 14) was 3.3% at most when that from the cages where 3 mice (No. 1-3, 4-6, 10-12, 15-17) were located was 2.80

to 22.81%. This was caused due to overlapping between mice while wandering around the chamber and the mice often stayed at the back of the chamber received relatively smaller dose. The absorbed dose to the mice compared to the expected dose of 0.1 Gy was less by 1% ~ 42% and the variations from the average absorbed dose was ± 34%.

The average absorbed dose in mice was 0.0959 Gy at 5th floor (No. 1-5), 0.0958 Gy at 4th floor (No. 6-10), 0.0969 Gy at 3rd floor (No.11-15), 0.0971 Gy at 2nd floor (No. 16-20), and 0.097 Gy at 1st floor (No. 21-23). The difference of average dose between floors was not significant as shown. The difference between the site-specific absorbed dose in mice is less than 3.09%, and the difference between the absorbed dose and the expected dose of 0.1 Gy was 6% at most. The variations from the average absorbed dose was ± 3% at most and the absorbed dose between the sites or the floors were consistent.

4. Discussion

In this study, the system that allows the accurate irradiation using the ^{137}Cs gamma irradiator mainly used in Radiation Biology was developed and the accuracy of the system has been confirmed by the experiments. The dose delivery using the conventional system had the variation of 42% at most whereas the variation was less than 6% for the mouse apartment. From the MCNP simulation, the difference between each chamber was less than 0.1% and 0.4% for the air kerma and the absorbed dose respectively. Considering the statistical error of MCNP and the assumption from the simulation, the accuracy of the simulation was matched well with the measurements with the glass dosimeters.

From this study, the mouse apartment can provide the reliable results used for the biological effects of the low-dose radiation and used for establishing the data for other radiobiological research and effective method to irradiate the biological samples.

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REFERENCES

[1] BCSH Blood Transfusion Task Force: Guidelines on gamma irradiation of blood components for prevention of transfusion associated graft-versus-host disease. Transfus Med 6:261-271 (1996)

[2] Piesch E, Burgkhardt B, Vilgis M: Photoluminescence dosimetry: rogress and present state of art. Radiat Prot Dosim 33:215–216 (1990)

[3] Tsuda M: A few remarks on pholuminesce dosimetery with high energy x-ray. Jpn J Med 20:131-139 (2000)

[4] Technical Report: Explanation material of RPL glass dosimeter. Small Element System. Asahi Techno Glass Corporation, Tokyo, Japan (2000)

[5] Hoshi Y, Nomura T, Oda T, et al: Application of a newly developed photoluminescence glass dosimeter for measuring the absorbed dose in individual mice exposed to low-dose rate 137Cs ɣ-rays. J Radiat Res 41:129–137 (2000)

[6] Technical Report: Explanation material of RPL glass dosimeter. Small Element System. Asahi Techno Glass Corporation, Tokyo, Japan (2000)