ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 9(25), DOI: 10.17485/ijst/2016/v9i25/97175, July 2016*

The Development of Bismuth Shielding to Protect the Thyroid Gland in Radiations Environment

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Abstract

Background/Objectives: In order to protect thyroid gland and provide medical support in national catastrophe of radiation leakage, this study aimed to develop bismuth eco-friendly radiation shielding that does not contain lead. **Methods/Statistical Analysis**: It manufactured bismuth shielding and evaluated the characteristics of shielding medical radiation to protect thyroid gland and the quality of images. **Findings**: In medical radiation area, shielding characteristics of bismuth shielding was, 84% with 0.12 mm thickness, 92% with 0.25 mm thickness, and 96% with 0.5 mm thickness, showing rising efficiency as the thickness increased. In the images that used bismuth shielding of 0.12 mm thickness, image contrast was 4.9±0.4, clarity of boundaries 4.8±0.3, and lesion detection rate 4.8±0.3, showing similar image quality to the images obtained without shielding. In the images with bismuth shielding of 0.25mm thickness, image contrast was 3.0±0.1, clarity of boundaries 3.3±0.2, and lesion detection rate 3.1±0.1, and in the images with bismuth shielding of 0.5 mm thickness, image contrast was 2.9±0.1, clarity of boundaries 3.1±0.2, and lesion detection rate was 3.0±0.1. **Improvements/Applications**: Based on these results, in order to obtain the optimal medical images and reduce exposure dose of medical radiation, it is recommended to develop environment-friendly and light bismuth shielding with proper shielding capability.

Keywords: Bismuth, Exposed Dose, Glass Rod Detector, Panorama Graphy, Thyroid

1. Introduction

With the development of modern industrial technology, the areas that use radiation and its application technology are getting more and more diverse. The use of radiation is constantly diversified and expanded in many fields such as nuclear weapons and nuclear power sector, diagnosis and treatment of disease, radiation sterilization, plant breeding, fire alarms, research and analysis on resources, material processing, screening system to prevent smuggling.

Such technology that uses radiation is becoming central factors in the development of national science technology such as national defense science and technology, public health, and national environmental monitoring[1].

With the rapid increase in the use of radiation, it is expected that there will be higher possibility of radiation accidents and increasing demand for safety measures at national level[2,3].

Radiation exposure dose on humans is, in case of natural radiation, 2.4 mSv per year on average, and in case of artificial radiation, 0.8 mSv per year. Among artificial radiation exposure, what takes the highest exposure dose is exposure by medical purpose, which amounts to 0.65 mSv. These figures show that exposure by medical purpose takes the highest portion of artificial radiation exposure, 81% of the total[4].

Medical radiation gained validity and is being used in medicine as it has more advantages in patients' diagnostic information than damages from radiation. In addition, to optimize radiation protection for patients, it is made for optimal images that suit the concept 'ALARA (As Low as Reasonably Achievable)' and minimize the exposure dose for patients[5–9].

In order to reduce radiation exposure, currently most shielding is made by dispersing lead in rubber, using extrusion molding, and producing sheet forms. This kind of shielding made of lead is relatively heavy, categorized

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as heavy metal, and raises human and environmental hazards. Therefore, to solve these problems, there have been researches to develop sheets that are light and wearable, harmless to human body, and can shield direct and indirect radiation exposure[10,11].

With the improvement of living standard, the use of medical radiation is gradually increasing. Especially, the use of radiation in dentistry is rapidly rising. The area that requires managing the exposure dose in dentistry is panoramic radiography. In Korea, the number of dental panoramic devices in 2002 was 5,533 and it increased 2.5 times to 12,753 by December 2008. This statistics show that 90% of all dental clinics have panoramic devices and the frequency of panoramic radiography increased from 460,343 in 2002 to 1,712,510 in 2006[7,12] .

The repeated panoramic radiograph test is reported to affect crystalline lens, make them opaque, and can cause cataracts[13,14].

To reduce exposure dose to human body, radiation shielding made of lead is mainly used but it is radiopaque so it affects getting necessary images for diagnosis. For this reason, researches are conducted to find shielding that is radiolucent to some extent and can reduce exposure dose at the same time, but as for now, base data is insufficient[15–19].

Glass rod detector enables repeated measurement and reading, has wide measurement range, has less fading effects, and has good direction and energy dependence so recently it is a frequently used dose measurement system in the research on radiation exposure dose[20–25].

Under the circumstances, in order to provide medical support in national disaster of radiation leakage, this study aims to produce Bismuth environment-friendly radiation shield that does not contain lead, use panoramic test devices that use glass rod detector and medical radiation energy, evaluate the shielding characteristics to protect thyroid gland against medical radiation and image quality, and test its usefulness.

2. Research Object and Method

2.1 Manufacturing Bismuth Shielding Sheet

As effective materials that can shield thyroid gland in medical radiation, bismuth and barium, which do not contain lead so are harmless to human body and light and economical, were selected. By additionally adding silicone polymer, which nano-converts barium sulfate ($BaSO_4$) and bismuth oxide (Bi_2O_3) so mixes well, and tourmaline, which has a high absorption rate in X-ray images and has electrical characteristics, shielding sheet was manufactured[10]. Bismuth shielding sheets were made to be 0.12 mm, 0.25 mm, 0.5 mm thick and were tested for shielding efficiency.

2.2 Evaluation of Shielding Efficiency to Protect Thyroid Gland in Medical Radiation

In order to evaluate the shielding efficiency to protect thyroid gland in medical radiation field, dental panoramic test device, GENORAY GDP-1 was used with scan condition, 68 kVp 7 mA 17 sec. To measure exposure dose of examinees, whole body human phantom (Model PBU-31, Kyoto Kagaku, Japan) that is made of materials equivalent to human body was used (Figure 1).

The measurement of exposure dose to evaluate the shielding efficiency to protect thyroid gland was conducted 5 times for each bismuth shielding of different thickness, and the average and standard deviation were calculated[5,7] .

2.3 Measurement of Exposure Dose of Glass Rod Detector

Glass rod detector, Dose Ace (Model GD-352M and FGD-1000, Asahi Techno Glass Cooperation, Shizuoka, Japan), was used. As for calibration of the glass rod detector, ^{137}Cs radioactive standard of Japanese Radiation Standard was used and calibration was conducted with glass element that was irradiated of 6 mGy.

Considering the characteristics of elements, before irradiation, the shielding went through annealing process, by which it was heated at 400°C for an hour and cooled

Figure 1. Radiation generator and phantom.

down, and its background value was measured and 10-20 μGy was gained. Then after panoramic scan, the shielding was pre-heated at 70°C for an hour and cooled down, and the radiation dose that was irradiated was read ten times repeatedly through a reader, and the average and standard deviation were calculated. From the calculated value, background value was deducted and the value of exposure dose was derived.

2.4 Qualitative Evaluation of Images Gained through Bismuth Shielding

Using skull phantom with radiation condition, 68 kVp, 7mA, 17sec, images depending on different thickness of bismuth shielding was obtained and they were analyzed qualitatively to prove its clinical usefulness. For qualitative analysis, regarding image contrast, lesion detection rate, clarity of boundaries of each image, a group made up of 1 dental specialist, 2 radiologists with more than 10 years of experience, and 2 dental hygienist evaluated using 5 point Likert scale.

3. Conclusion and Considerations

3.1 The Result of Evaluating Shielding Efficiency of Bismuth Shielding to Protect Thyroid Gland in Medical Radiation Energy Area

Bismuth shielding in medical radiation energy area has advantages-it is light, environment-friendly, and does not contain lead so it is harmless to human body-so is researched for its potential as radiation shielding but is still in the initial stage[10]. There has been a research[16] on the usefulness of bismuth shielding in reducing exposure dose to crystalline lens or reproductive system in CT (Computed Tomography), but there have been almost no researches on decreasing exposure dose depending on different thickness of bismuth shielding.

So, this study manufactured bismuth shielding with 0.12 mm, 0.25 mm, and 0.5 mm thickness, and tested its shielding efficiency. With 0.12 mm thickness, shielding efficiency was 84%, with 0.25 mm thickness, 92%, and with 0.5 mm thickness, it was 96%, so as the shielding was thicker shielding efficiency increased.

If shielding gets thicker and provides poor wearablity and shields scattered radiation, not direct radiation, it will be hard to use thick shielding. In that case, referring to the following result, appropriate thickness can be selected and used depending on different cases (Table 1).

3.2 The Result of Evaluating Image Quality of Bismuth Shielding to Protect Thyroid Gland in Medical Radiation Energy Area

In dental panoramic test, for the purpose of protecting radiation-sensitive thyroid gland and reducing exposure dose, medical institutions usually use shielding made of lead. However, thyroid gland shield made of lead creates cone-shaped radiopaque defect shade in dental panoramic images and hampers diagnosis (Figure 2).

For this reason, bismuth shielding, which is eco-friendly, light, and has relatively low radiopacity, was made with different thickness, and in order to test the usefulness of bismuth shielding in medical radiation area, images of dental panoramic test were obtained and their image quality was evaluated.

After obtaining dental panoramic images, concerning image contrast, lesion detection rate, clarity of boundaries of each image, a group consisting of 1 dental specialist, 2 radiologists with more than 10 years of experience, and 2 dental hygienist evaluated using 5 point Likert scale.

Table 1. Styles shielding efficiency depending on the thickness of bismuth shielding

Bismuth Thickness (mm)	exposure dose on surface (μGy)	exposure dose after penetration (μGy)	Shielding Rate(%)
0.12	977.3±3.84	156.3±0.84	84
0.25	977.3±3.84	78.2±0.79	92
0.5	977.3±3.84	39.1±0.72	96

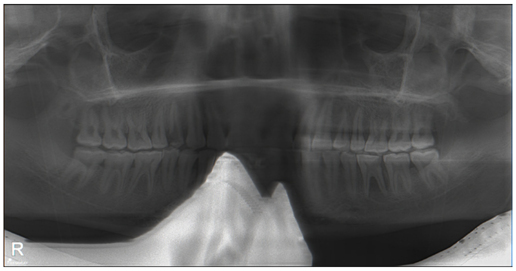

Figure 2. A dental panoramic image when 0.5 mm lead shielding was used.

Image contrast, lesion detection rate, and clarity of boundaries when shielding was not used were set as reference points at 5.0±0.0. In the images with bismuth shielding of 0.12 mm thickness, image contrast was 4.9±0.4, lesion detection rate 4.8±0.3, and clarity of boundaries 4.8±0.3, which were similar values to those measured without shielding (Table 2.), (Figure 3).

In the images with bismuth shielding of 0.25 mm thickness, image contrast was 3.0±0.1, lesion detection rate 3.1±0.2, and clarity of boundaries 3.3±0.1 (Table 2.), (Figure 4).

In the images with bismuth shielding of 0.5 mm thickness, image contrast was 2.9±0.1, lesion detection rate 3.0±0.2, and clarity of boundaries 3.1±0.1 (Table 2.), (Figure 5).

As can be seen from the results, to obtain diagnostically significant images using bismuth shielding and

Table 2. Evaluation of the clinical images

Item	Bismuth Thickness(mm)				p-value
	Non	0.12	0.25	0.5	
Contrast	5.0±0.0	4.9±0.4	3.0±0.1	29±0.1	<0.05
Clarity of boundaries	5.0±0.0	4.8±0.3	3.1±0.2	3.0±0.2	
Lesion detectability	5.0±0.0	4.8±0.3	3.3±0.1	3.1±0.1	

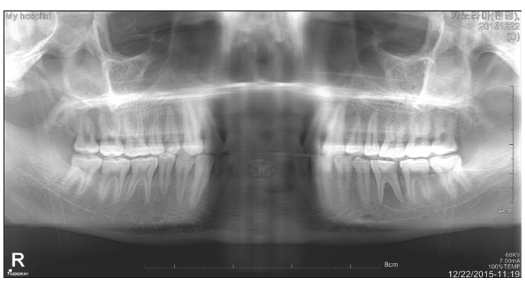

Figure 3. A dental panoramic image when 0.12 mm bismuth shielding was used.

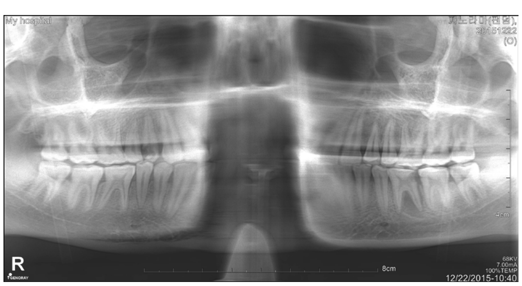

Figure 4. A dental panoramic image when 0.25 mm bismuth shielding was used.

Figure 5. A dental panoramic image when 0.25 mm bismuth shielding was used.

to protect thyroid gland, bismuth shielding of 0.12 mm thickness is thought to be appropriate.

This result is similar to the results of Kim's study[11] on the shielding effect of scattered radiation by bismuth shielding in CT (Computed Tomography) test and also similar to study in[15] on the effect of a thyroid shield made of a tissue-equivalent material on the reduction of the thyroid exposure dose in panoramic radiography. Also, taking a step further, this study is significant in that it provided data for developing shield that will offer optimal images and effectively lower exposure dose.

These results are thought to serve as reference data in developing eco-friendly, light radiation shielding to obtain optimal medical images and reduce exposure dose by medical radiation.

In order to minimize exposure dose of radiation on human being, relevant organizations or institutions that use radiation should provide radiation inspection personnel with regular education sessions on exposure dose and image quality to gain legitimacy, and should make efforts to achieve the optimal radiation protection for patients.

4. Conclusions

In order to protect thyroid gland and provide medical support in national catastrophe of radiation leakage, this study aimed to develop bismuth eco-friendly radiation shielding that does not contain lead. It manufactured bismuth shielding and evaluated the characteristics of shielding medical radiation to protect thyroid gland and the quality of images.

In medical radiation area, shielding characteristics of bismuth shielding was, 84% with 0.12 mm thickness, 92% with 0.25 mm thickness, and 96% with 0.5 mm thickness, showing rising efficiency as the thickness increased. In the images that used bismuth shielding of 0.12 mm thickness, image contrast was 4.9±0.4, clarity of boundaries 4.8±0.3, and lesion detection rate 4.8±0.3, showing similar image quality to the images obtained without shielding. In the images with bismuth shielding of 0.25 mm thickness, image contrast was 3.0±0.1, clarity of boundaries 3.3±0.2, and lesion detection rate 3.1±0.1, and in the images with bismuth shielding of 0.5mm thickness, image contrast was 2.9±0.1, clarity of boundaries 3.1±0.2, and lesion detection rate was 3.0±0.1.

Based on these results, in order to obtain the optimal medical images and reduce exposure dose of medical radiation, it is recommended to develop environment-friendly and light bismuth shielding with proper shielding capability.

5. Acknowledgment

This research was supported by a Gimcheon University research grants in 2016.

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