SKIN EXPOSURE REDUCTION USING AIR GAP IN INTERVENTIONAL RADIOLOGY

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Abstract: Radiation skin injury of patients is an important problem in interventional radiology. One of the causes is the scattered rays from the catheter table. To reduce these scattered rays, polystyrene foam is placed between the catheter table and the subject as an air gap. In this study, the adequate thickness of the polystyrene foam was investigated for clinical practice. As a result, 2 cm thick polystyrene foam was used to simulate the air gap, resulting in a surface dose reduction of about 5%. In interventional radiology procedures, the air gap method using polystyrene foam will reduce the radiation skin injury of patients.

Introduction

Recently, interventional radiology procedures (IVR) including transcatheter arterial embolization (TAE) and percutaneous transluminal angioplasty [1-2] (PTA) are indispensable, because they have a low invasiveness compared with surgical operation. However, radiation induced skin injury of patients is an important problem in IVR. Since radiation induced skin injury is a deterministic effect of radiation, once a threshold dose has been exceeded, the severity of injury increases with increasing dose[3-4]. In 1994, the Food and Drug Administration (FDA) reported on early and late skin injuries, and recommended that skin doses be recorded when they might be high enough to cause skin injury[5].

In order to reduce skin exposure, the low energy rays must be decreased. The low energy scattered rays are useless for image quality, but scattered ray removal is effective for skin exposure reduction. During IVR, procedures are performed under a tube system in many cases; the catheter table generates the scattered rays.

In the past, absorption and scattering of the catheter table was not investigated, because it could not be moved physically during procedures. However, since a report that the carbon couch for radiotherapy causes X-ray attenuation of more than 15% [6], it is guessed that the catheter table for IVR also has equal absorption.

Then, if the catheter table absorbs the primary rays, we believe that the catheter table generates the scattered rays. These scattered rays will stop at the skin of the patient is back, and lead to increased skin exposure. The aim of this study was to devise a method to remove the scattered rays from the catheter table. For this method, we inserted an air gap between the catheter table and the patient. The air gap method is known to improve image quality in diagnostic radiographs by scattered ray removal [7-9].

In this study, the possible use of polystyrene foam was evaluated as a substitution for the air gap, which cannot be geometrically made between the catheter table and the patient.

Materials and Methods

1. Variation in the subject surface dose by catheter table placement.

Experiments were performed using a typical X-ray unit, and exposure conditions were 38 keV (effective energy) and 200mAs. A Mix-Dp plate was used for the subject, and the thickness was set at 20 cm. The catheter table was placed between the X-ray tube and the subject. The 0.03 cm^3 parallel plate ionization chamber was placed on the subject is surface. The exposure field was 15*15 cm^2 on the subject is surface, and focal surface distance (FSD) was set at 60cm (Fig 1).

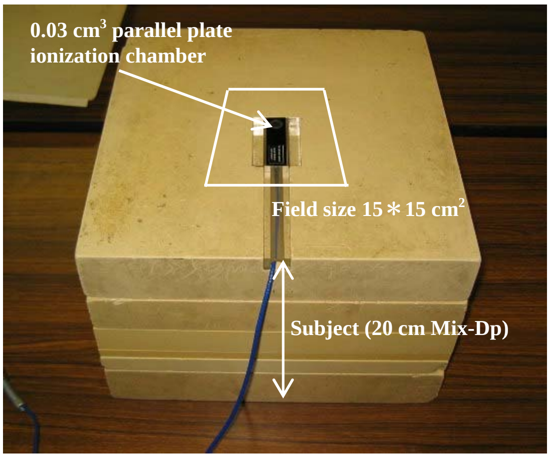

Figure 1: Arrangement of detector for dosimetry.

The catheter table was separated from the subject by 30 cm, and then we measured the subject is surface dose. For the subject is surface dose, we detected only primary rays which transmit from the catheter table.

Then, the catheter table was placed in contact with the subject, and we again measured the subject is surface dose. This time we detected both scattered rays and primary rays.

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If these two cases of measurements are subtracted from each other, only scattered rays remain.

The geometric arrangement of the experiments is shown in Fig 2.

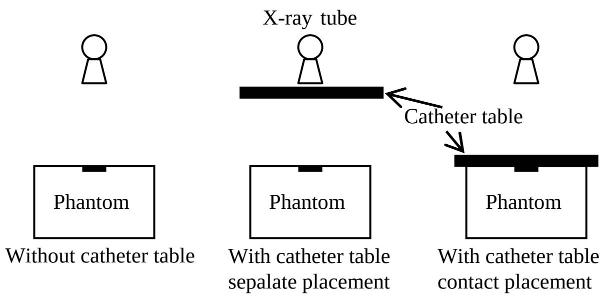

Figure 2: Geometric arrangement of experiment 1.

2.The scattered ray removal effect of the air gap.

As shown in Fig 3, an air gap was inserted between the catheter table and the subject, and then the subject is surface dose was measured. Air gap thickness was varied from 2 to 14 cm. Furthermore, the subject axial depth doses (12 cm) for each air gap thickness were measured.

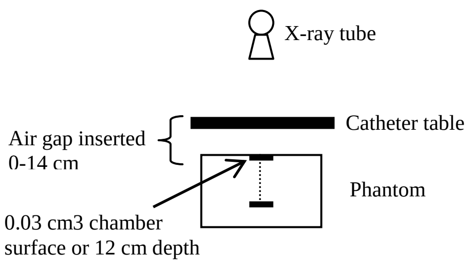

Figure 3: Geometric arrangement of experiment 2.

3. Efficacy of the polystyrene foam as an air gap substitution.

3-1. The subject dose when using polystyrene foam as an air gap substitution.

The polystyrene foam was inserted between the catheter table and the subject, and the subject is surface dose was measured. The polystyrene foam thickness was varied from 2 to 14 cm.

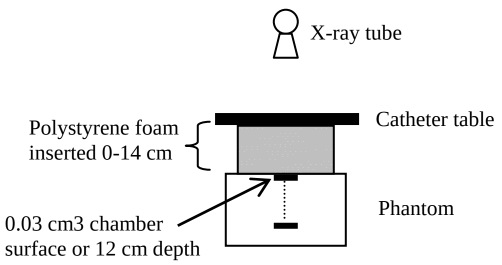

Figure 4: Geometric arrangement of experiment 3-1.

The subject depth doses were measured in order to evaluate primary ray absorption by the polystyrene foam. The geometric arrangement of the experiments is shown in Figs 4 and 5.

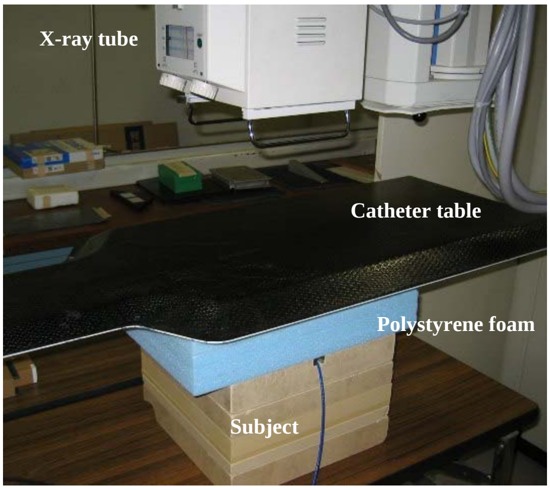

Figure 5: Experiment practical view.

3-2. X-ray absorption inherent in the polystyrene foam.

Since the polystyrene foam used for this study has a slight density of 28kg/m^3, primary ray absorption did not occur. Then, absorption and scattering inherent in polystyrene foam was measured. As shown in Fig 6, the polystyrene foam was separated from the subject from 30 cm. For the subject is surface dose, we detected only primary rays which transmit through the polystyrene foam. Then, the polystyrene foam was placed in contact with the subject. This led to the detection of both scattered rays and primary rays. If these two cases of measurements are subtracted from each other, only scattered rays remain.

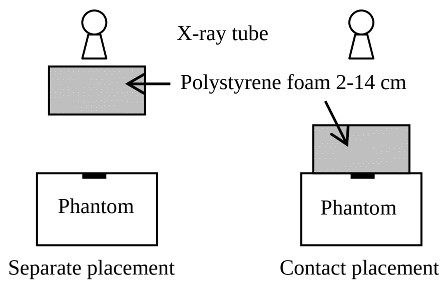

Figure 6: Geometric arrangement of experiment 3-2.

Results

1. Variation in the subject is surface dose by catheter table placement.

When the catheter table was separated from the subject by 30 cm, the subject is surface dose decreased by about 18% as compared with the time of not using the catheter table. On the other hand, when the catheter table was placed in contact with the subject, the subject

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is surface dose increased by about 4% as compared with the time of not using the catheter table.

The dose obtained by the former consisted of the attenuated primary rays. The dose obtained by the latter consisted of the scattered rays from the catheter table and the attenuated primary rays. The scattered rays were computed at 21% by subtracting the two kinds of experimental results (Fig 7).

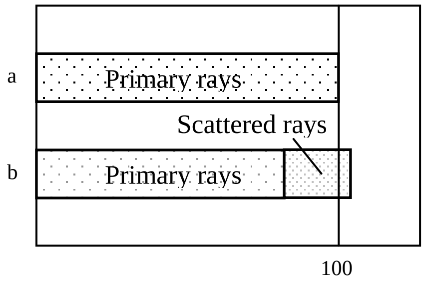

Figure 7: The rates of primary and scattered X-rays by catheter table insertion. (a) Without catheter table (b) With catheter table

2. The scattered ray removal effect of the air gap.

The relative surface dose changes with changes in air gap thickness are shown in Fig 8. When inserting a 2 cm air gap between the catheter table and the subject, the relative surface dose decreased to about 90%, after that, with increasing air gap thickness, the relative surface dose decreased gradually. On the other hand, at the 12 cm axial depth, doses remained were unchanged regardless of air gap thickness.

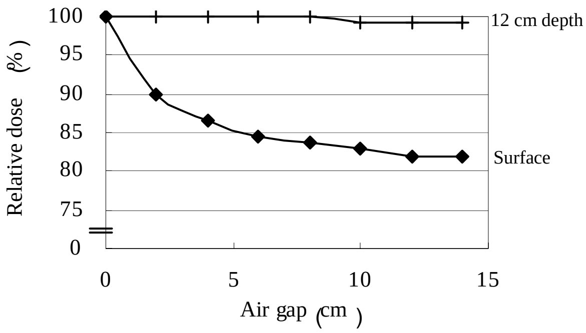

Figure 8: The relative dose with air gap thickness.

3. Efficacy of polystyrene foam as an air gap substitution.

3-1. The subject dose when using polystyrene foam as an air gap substitution.

Relative surface dose changes when using polystyrene foam as an air gap substitution are shown in Fig.9. When inserting 2 cm thick polystyrene foam between the catheter table and the subject, the relative surface dose decreased to about 90%. Similarly, when 14 cm thick polystyrene foam was inserted, the relative surface dose decreased to about 79%. Moreover, at the 12 cm axial depth, doses decreased according to polystyrene foam thickness.

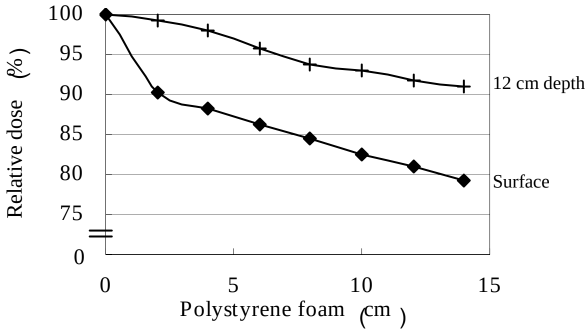

Figure 9: The relative dose with polystyrene foam thickness.

3-2. The X-rays absorption inherent in the polystyrene foam.

As shown in Fig.10, when the polystyrene foam was separated from the subject by 30 cm, the relative surface dose decreased according to increasing polystyrene foam thickness. On the other hand, when the polystyrene foam was in contact with the subject, the relative surface dose increased when using up to 4 cm thick polystyrene foam. The scattered rays obtained by subtracting the two kinds of experimental results were increased according to the polystyrene foam thickness, and were saturated with 10 cm.

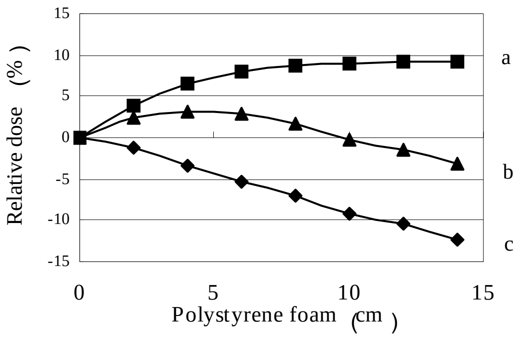

Figure 10: Absorption and scattering by the polystyrene foam. (a) Scattered rays. (b) Attenuated primary rays plus scattered rays. (c) Attenuated primary rays.

Discussion

1.Variation in the subject is surface dose by catheter table placement.

The surface dose decreased when a 30 cm gap existed between the subject and the catheter table. On the other hand, the surface dose increased when the catheter table was in contact with the subject. The dose obtained by the former was the attenuated primary rays. The dose obtained by the latter added the scattered rays from the catheter table to the attenuated primary rays. This suggested that the catheter table was causing an increase in the subject's surface dose. The reason for this is the scattered rays from the catheter table. These scattered rays do not contribute to image quality.

2. The surface dose reduction effect of the air gap.

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The subject is surface dose was decreased by the presence of an air gap between the catheter table and the subject. This suggested that the scattered rays from the catheter table were removed by the air gap. Relative surface dose decreased to 82% with a 14 cm air gap. On the other hand, the 12 cm depth dose remained constant regardless of air gap depth. In short, air gap does not affect exit dose.

3. Efficacy of the polystyrene foam as an air gap substitution.

The subject is surface and depth dose decreased when the polystyrene foam was placed between the catheter table and the subject (Fig 9). This decrease of depth dose showed that the polystyrene foam absorbed primary rays. Moreover, it is necessary to take into consideration the influence of slight scattered rays from the polystyrene foam.

In addition, polystyrene foam marginally generates scattered rays. In Fig 9, since these factors were not taken into consideration, accuracy is lacking. Then, the relative dose, which compensated for these factors, is shown in Fig 11. The relative dose in Fig 11 shows the air gap effect when using polystyrene foam between the catheter table and the subject. The relative dose decreased about 5% when 2 cm thick polystyrene foam was used, and the use of 6 cm thick polystyrene foam or thicker was ineffective.

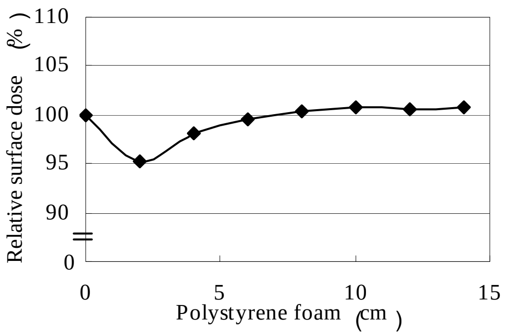

Figure 11: The air gap effect of the polystyrene foam.

Since this method provides the possibility of surface dose reduction additionally, it is necessary to examine different materials which can be used to form an air gap in the future.

Conclusions

The air gap method can remove scattered rays from the catheter table effectively, resulting in surface dose reduction. Two cm thick polystyrene foam was used to simulate the air gap, resulting in a surface dose reduction of about 5%. In interventional radiology procedures, this method will be effective for the prevention of radiation skin injury, is easy to set up and inexpensive.

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