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Development of Shielding using Medical Radiological Contrast Media; Comparison Analysis of Barium Sulfate Iodine Shielding ability by Monte Carlo Simulation

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ABSTRACT

The purpose of this study is to estimating the possibility of manufacturing radiation shielding sheet by searching for environmentally friendly materials suitable for medical environment of medical radiation shielding. There are many tungsten products which are currently used as shielding materials in place of lead, but there are small problems in the mass production of lightweight shielding sheets due to economical efficiency. To solve these problems, a lightweight, environmentally friendly material with economical efficiency is required. In this study, Barium sulphate and Iodine were proposed. Both materials are already used as contrast medias in radiography, and it is predicted that the shielding effect will be sufficient in a certain region as a shielding material because of the characteristic of absorbing radiation. Therefore, in this study, we used a Monte Carlo simulation to simulate radiation shielding materials. When it is a contrast agent such as Barium sulfate and Iodine, the radiation absorption effect in the high energy region appears greatly, and the effectiveness of the two shielding substance in the energy region of the star with thickness of 120 kVp is also evaluated in the medical radiation imaging region. Simulated estimation results it was possible to estimate the effectiveness of shielding for all two substances. Iodine has higher shielding effect than barium sulfate, 0.05 mm thick appears great effect. Therefore, the Monte Carlo simulation confirms that iodine, which is a radiological contrast agent, is also usable as barium sulfate in the production of radiation shielding sheets.

Keywords : Radiation shield, iodine, Barium sulfate, Monte Carlo Simulation

Ⅰ. INTRODUCTION

Contrast media used will be in medical radiography are mainly used in the field of X-ray inspection for the purpose of diagnosis and treatment using difference in radiation absorption. Especially, it can be used in the gastrointestinal tract, blood vessel, cerebrospinal fluid, articular cavity and the like, which have difficulty in contrast of shading with the general radiography, so that an X-ray image having a high contrast ratio can be obtained.[1] Barium sulfate and iodine are the most commonly used materials for contrast media screening using X-rays. Iodine is highly safe and widely used for vascular disease tests, and barium sulphate has been widely used in the digestive system.[2-4] The contrast effect can be adjusted according to the concentrations of both substances of the two components, and the volume and concentration are adjusted according to the examination site, the examination technique, and the condition of the patient.[5-7] The X-ray attenuation of the contrast media, when the average energy is greater than the energy of the K-stage energies, produces a

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good photoelectric effect and displays a large difference in X-ray absorption, and consequently the contrast agent is in the region absorbing the radiation The K-absorption edge (K-wadge) of the barrier (Ba) is 37.4 keV and I is 33.17 keV.[8] In the case of Iodine, the mass absorption coefficient is 6.6 ㎠/g, which is slightly lower than the K-absorption edge, but the absorption coefficient is 36 ㎠/g, which is slightly higher than the K-absorption edge Therefore, the absorption of X-rays is increased to affect the image. In previous studies, a study using a Barium Sulfate was performed in general, but in this study, we tried to expand the range of Contrast Media.[9-10] If this energy absorption result is applied as a radiation shielding material, a radiation shielding sheet having excellent shielding power in a specific energy region can be developed. Therefore, in this study, we tried to compare the shielding ability of Barium sulfate and Iodine by thickness X-ray absorption energy by using the Monte Carlo simulation.

Ⅱ. MATERIAL AND METHODS

This study simulated the shielding ability of Barium Sulfate ($BaSO_4$) and Iodine (I) by MCNP (Monte Carlo N-Patricle Extended, Los Alamos National Laboratory , USA). Monte Carlo code MCNPX v 2.6 program, and the input tube voltage to the Monte Carlo code is acquired by using the SRS-78 program provided by IPEM and input to the MCNPX. And was constructed in the same manner as the radiation generation conditions used in the general medical field.[11-14] The shielding ability of each shielding material was set to 0.02 mm, 0.05 mm, 0.08 mm, and 0.1 mm for each thickness. This is the thickness of the sheet that can be manufactured in general.

The area of the sheet was proposed with a square of 15 ㎠. The atomic numbers of the constituent materials in the compound of barium sulfate were coded with barium 56, sulfur 16 and oxygen 8, and the density was 4.5 g/㎤, and the atomic number of the iodine was 53 and 4.93 g/㎤.

X-ray photon movement was defined using P Mode to track the energy spectrum of photons interacting with shielding materials and certain energy domains used in the medical field. The Cell & Surface Card set the importance of photons to "1" and the importance to "0" to prevent photons in vacant areas outside the specimen. Continuous X-ray energy in the 10 − 150 kV band was applied as the radiation source used in the Monte Carlo simulation. At this time, the energy gap used in the experiment was defined as the tube voltage of the X-ray tube, 13.4 % of the Mac rate, and 2.1 mmAl of the used filter. The anode target was defined by the tungsten. In the case of tube voltage, an energy distribution map was created based on 120 kVp in order to simulate estimation from the area of high voltage.

In the present experiment, the spectral distribution was constructed by using the maximum energy to compare the shielding capacities of the two components, although it was applied from the energy range 40 kVp used for the human body. ERG defined the histogram of energy of seafarers by using the energy distribution data of continuous X-ray photon using sailor information (SI) and seafarer probability (SP). Sampling of the source particles uses SUR to generate X-ray photons on the surface of Barium and Iodine tetrahedral specimens, and PAR, which defines the source particle type, uses PAR2, a photon, to cause photons incident on one surface of the X- We estimated the probability of passing through the surface to 50,000 events. In addition, the shielding performance of the two materials was compared by composing them into sheets. In order to compare the thicknesses of the same conditions, the shielding factor was calculated as (1-W/W0)×100. At this time, W is the photon energy value when there is a shield between the X-ray beam and the detector, W0 is the simulation of the photon energy value in the absence of shielding between the X-ray beam and the detector.

Ⅲ. RESULT

The direct utilization of the shielding substance within the general radiographic imaging range can be explained by a method of increasing the photoelectric effect and improving the absorption value. Comparing Barium sulfate and Iodine, which is a radiation absorbing material used in the human body, we compared the shielding ability of the thickness and the energy shielding ability. As shown in Fig. 1, when it is barium sulfate, as already known, it has an absorption limit of 37 keV (K-Edge), showing an effective difference for each thickness. Fig. 2 shows the result of Iodine. And it had an absorption edge on the same energy area base as Barium sulfate. However, unlike barium sulfate, in the high energy region, it expresses a safe shielding function, and even in the region of different thickness, the difference between 0.05 mm and 0.1 mm was not greatly expressed.

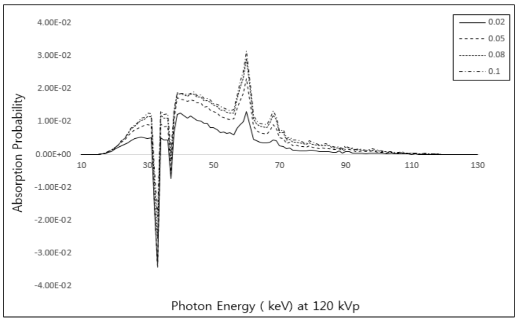

Fig. 1. Absorption probability as a function of photon energy Barium compound.

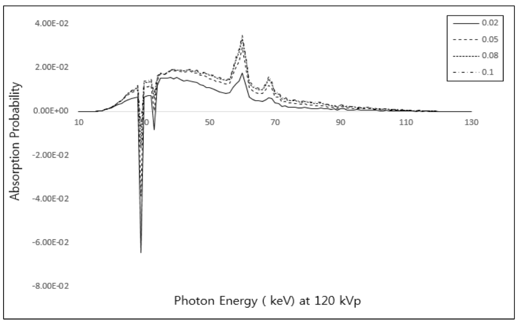

Fig. 2. Absorption probability as a function of photon energy Iodine.

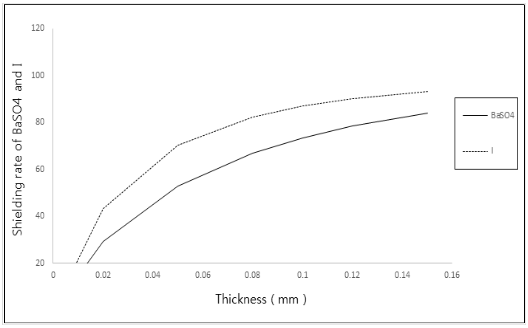

Fig. 3. Shielding rate as a function of material thickness Barium and Iodine.

All of the two materials have a radiation absorbing effect, and the radiation shielding effect can be sufficiently explained. Therefore, as shown in Fig. 3, it is possible to make 0.15 mm according to estimation using the maximum value of the thickness that can be commercialized, that is, 120 kVp to produce a shielding sheet using this material. In addition, the shielding effect of Iodine over Barium sulfate was greater than 10~15 %.

Ⅳ. DISCUSSION

Medical radiation area platform radiation protection is done in various ways. Various methods have been proposed, escaping from past lead dependent methods. Production of shielding sheet began with weight reduction of apron, but as a recent medical radiation shielding material, we are looking for environmental radiation shielding material harmless to the human body.[15] The most practical alternative is tungsten, but the problem is economic. As economical substances, bismuth oxide, tin and the like can be provided.

However, similar to the results of this study, harmless substances include Iodine and Barium sulfate. Barium sulfate is widely used, but iodine which is a halogen element has an atomic number of 53, a density of 4.933 g/cm^3, and barium sulfate belongs to a larger one at a density of 4.5 g/cm^3.[16,17] Since the two materials are all excellent in miscibility, it is possible as a material for the shielding sheet if a substance is mixed into a certain base material.

Another characteristic of radiological contrast media is their absorption energy range. The use range of the X-ray tube voltage used in the medical radiation field is 50 to 150 kVp, and this X-ray has been expressed in the range of the continuous spectrum, but the average energy is about 1/3 to 1/2 of the maximum energy. Therefore, in the case of a low dose shield, light shielding clothing can sufficiently protect it, but direct line exposure of scattered rays becomes a problem in the high tube voltage region. For contrast media used in medicine, the higher the concentration, be absorb in radiation the more effective it is.[18] Therefore, by using the Iodine concentration adjustment point well, it is also possible to shield by sufficient area.

Radiographic contrast media induce high voltage imaging in the imaging process of the radiographic region.[19] The purpose is to increase the amount of absorption of the contrast material by increasing the energy area to absorb more radiation than the photoelectric effect absorbed from the bone. Therefore, as can be seen from the results of this study, when estimating using 120 kVp, the thickness of the pure shield can be as much as 0.15 mm. High energy shielding is possible with the lightweight materials, conditions such as environmentally friendly materials can satisfy all radiological contrast media. Monte-Carlo simulations can be used to estimate the shielding capability of the 120kVp energy band.

Ⅴ. CONCLUSION

Monte Carlo simulation confirmed that both Iodine and Barium sulfate are possible as radiation shielding materials. When fabricating on a shielding sheet under the same radiation generation condition, it is also possible to achieve the purpose of light weight of 0.15 ㎜ in thickness. More than anything, it is a harmless material of the human body, and it can be recommended with a material excellent in both workability and economy. In this study, it can be estimated that Iodine is superior in shielding ability under the same conditions as Barium sulfate.

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의료방사선 조영제를 이용한 차폐체 개발; 몬테카를로 시뮬레이션을 통한 황산바륨과 요오드의 차폐능 비교분석

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요 약

본 연구는 의료방사선 차폐를 위해 의료 환경에 적합한 친환경 소재를 찾아 방사선 차폐 시트 제작의 가능성을 추정하고자 하는 것이다. 현재 차폐 소재로 주로 사용되는 납을 대신한 텅스텐 제품이 많이 있으나, 경제성으로 인해 경량의 차폐 시트의 대량생산에는 다소 문제가 있다. 이러한 문제점을 해결하기 위해 경제성 있는 경량 친환경 소재를 필요로 한다. 이러한 소재로써 본 연구에서는 황산바륨과 요오드를 제안하였다. 두 물질은 방사선 촬영에서 이미 조영제로 사용되고 있어 방사선을 흡수하는 특성으로 차폐 재료로써 일정 영역에서 충분히 차폐효과가 있을 것으로 예측하고 있다. 따라서 본 연구에서는 방사선 차폐 재료로 검증하기 위해 몬테카를로 시뮬레이션을 이용하여 모의 추정하였다. 황산바륨과 요오드 등 조영제인 경우 고에너지 영역에서 방사선 흡수효과가 크게 나타나, 의료방사선 고관전압 촬영영역 120 kV의 두께별 에너지영역에서 두 차폐물질의 유효성을 평가하였다. 모의 추정 결과 두 물질 모두 차폐의 유효성을 추정할 수 있었다. 요오드가 황산바륨보다 차폐효과 높았으며, 0.05 ㎜ 두께에서는 효과성이 크게 나타났다. 따라서 방사선차폐 시트의 제작 재료로 방사선 조영제인 요오드도 황산바륨과 같이 가능하다는 것을 몬데카를로 시뮬레이션을 통해 확인 할 수 있다.

중심단어: 방사선 차폐체, 요오드, 황산바륨, 몬데카를로 시뮬레이션