Analysis of scattering rays and shielding efficiency through lead shielding for 0.511 MeV gamma rays

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Abstract. Radiation is harmful to human body and it is generally shielded with lead. However, lead is a high-atomic-number material that interacts with radiation to generate scattering lines, which is one of the causes of radiation exposure. In this study, we investigate the influence of scattering line generated from lead and the shielding efficiency through lead shielding based on 0.511 MeV gamma rays used in medical treatment. The experimental results indicated that the scattering line generated from lead was short and shielding was possible up to only a narrow space between lead and the human body. The shielding efficiency showed a shielding rate as low as 6% at 0.25 mmPb and 13% at 0.5 mmPb, when the scattering line was sufficiently reflected.

KEYWORDS: PET, Shieldnig, Lead

1 INTRODUCTION

Radiation causes radiation hazards in the human body. World Health Organization classifies radiation as a carcinogen[1]. There are three protection methods for radiation exposure: time, distance, and shielding. Among the shielding materials, lead exhibits the best radiation shielding property; therefore, lead aprons are employed in the medical environment. However, such aprons are not generally used in the positron emission tomography/computed tomography (PET/CT) environment where 0.511 MeV high-energy gamma rays are emitted[2,3]. The use of a lead apron cannot be justified due to the inconvenience caused by itsweight[4,5]. This study divides the skin into epidermis and dermis and compares the dose change depending on the existence or absence of lead shielding.

2 MATERIAL AND METHOD

2.1 Experimental material

In this study, experiments were conducted using the slab phantom [6,7] that represents calibration and the dose of human trunk. Table 1 lists the properties of the ICRU slab phantom.

Table 1: This is the table caption style. The caption appears before the table itself.

Geometry	Material	Element weight(%)	Density (g/cm^3)
ICRU Slab	PMMA (ICRU)	^{1}H(10.1), ^{6}C(11.1) ^{7}N(2.6), ^{8}O(76.2)	1.0

2.2 Experimental Method

In this experiment, one 0.511 MeV gamma ray was irradiated to the ICRU slab phantom using Monte Carlo N-P Transport Code (MCNPX, Los Alamos National Laboratory, ver.2.5.0, USA), which is a kind of Monte Carlo simulation. To evaluate the scattering rays generated from the lead shielding, first, a 0.511-MeV gamma ray was irradiated to the lead shielding that was in close contact with the ICRU slab phantom. Thicknesses of 0.25 mm and 0.5 mm were used for the lead shielding. Second, the removal rate of the scattering rays was measured while increasing the distance between the lead shielding and the phantom in centimetre units.

3 RESULT

3.1 Absorbed dose by site and lead thickness

Table 2 lists the measurement results of the absorbing dose for one 0.511-MeV gamma ray irradiated to the slab phantom with and without lead shielding.

Table 2. Absorbed dose by site according to lead thickness

Gy (J/kg)	Epidermis	Dermis	Slab
Without Pb	7.04E-15	8.42E-15	2.25E-15
0.25 mmPb	1.29E-14	8.06E-15	2.11E-15
0.5 mmPb	1.12E-14	6.88E-15	1.96E-15

3.2 Removal rate of scattering ray by air layer thickness

Table 3 lists the experiment results for the removal rates of the scattering rays by an air layer thickness between the lead shielding and phantom. When a 0.25 mm lead shielding was used, the scattering rays reaching the dermis with a 2 cm or thicker air layer were removed. For the epidermis, a 4 cm or thicker air layer was required. When a 0.5 mm lead shielding was used, the scattering rays reaching the dermis with 1 cm or thicker air layer were removed. For the epidermis, a 3 cm or thicker air layer was required.

Table 3. Removal rate of scattering rays by air layer thickness

	air gap	Epidermis (%)	Dermis (%)			
			0.05 mm	0.1 mm	0.15 mm	0.2 mm
0.25 mm Pb	1 cm	149	100	77	71	72
	2 cm	126	87	65	60	61
	3 cm	110	78	56	51	52
	4 cm	99	70	49	44	45
0.5 mm Pb	1 cm	130	87	68	64	65
	2 cm	112	77	59	55	56
	3 cm	98	69	51	48	49

4 CONCLUSION

Long-term exposure of medical practitioners to radiation in medical practices such as diagnosis and treatment using radiation leads to radiation-induced damage. In this study, skin doses through lead shielding with 0.511 MeV gamma rays were analysed. The scattering rays from lead were insignificant, and the shielding rate of the Lead shielding was 6%–13%, depending on the lead thickness. For the PET/CT workers who use radioisotopes with a 0.511 MeV energy, scattering rays are not an issue when using a lead apron. Therefore, they should make a choice about the discomfort and low radiation shielding rate of lead apron.

5 REFERENCES

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