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Determination of the Phantom Scatter Factor (S_p Factor) using a small Block in the Phantom

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New measurement method for S_p factors (Phantom Scatter Factors) is presented. The theoretical development of the approach is disscused showing that S_p factors can be obtained from three measurements of ionnization in a blocked, reference field and open field. This method has been tested using ^{60}Co gamma rays. The results were within 1% deviation between the theory and the experiment for the S_p facter. The new method does not need air measurement, and we could determine the S_p factors with a small piece of block

Key Words: Scatter Factor, Dosimetry

INTRODUCTION

The separation of the total scatter factor $S_{c,p}$ in a collimator scatter component, S_c, and a phantom scatter component, S_p, has proven to be an useful concept in megavoltage photon beam dose calcuations in situation which differ from the standard treatment geometry, since Holt and his colleagues[1] had propsed the concept of $S_{c,p}$, S_c, and S_p factors. In order to achieve electronic equilibrium, build-up cap was used for S_c factor measurement in the air. But it is not easy to measure that factors of high energy beam because of bulky build-up cap. Gasteren *et al*[2] and Khan[3] proposed the method of measuring the S_p or the S_c factors for high energy beam in the water phantom. But one should prepare heavy shielding blocks or fabricate a narrow cylindrical beam-coaxial polystyrene phantom, if we try to follow above method. In this study, we present a new measurement method for S_p factors (or S_c factors). This method has been tested using ^{60}Co gamma rays.

MATERIAL AND METHOD

1. Theory

It is well known that the total dose D_T at a point of interest in a phantom can be described by

$$D_T = D_P + D_S, \quad \cdots\cdots(1)$$

or

$$= D_{air} \cdot S_c\,(r) \cdot BSF\,(r) \quad \cdots\cdots(2)$$

where D_P is the primary component dose, D_S is the scattered, D_{air} is the dose in the air, S_c (r) is the collimator scatter factor of field size r, and BSF (r) the back scatter factor of field size r.[4]

Then we can analyse the dose components in Fig. 1.,

$$D_{open}\,(10) = D_{air} \cdot S_c\,(10) \cdot BSF\,(10) \quad \cdots\cdots(3)$$

$$D_{open}\,(r) = D_{air} \cdot S_c\,(r) \cdot BSF\,(r) \quad \cdots\cdots(4)$$

$$D_{block}\,(r, 10) = D_{air} \cdot S_c\,(r) \cdot BSF\,(r) - D_{air} \cdot S_c\,(r) \cdot BSF\,(10) \cdot (1 - T_r), \quad \cdots(5)$$

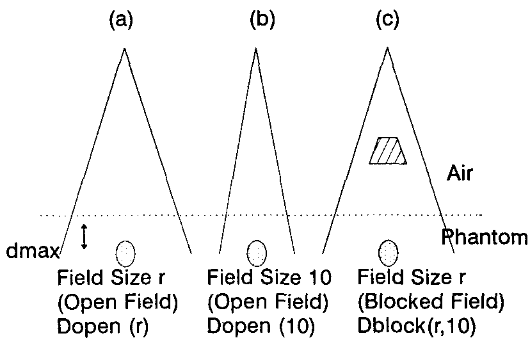

Fig. 1. Experimental setup for the determination of S_c factors. Dose rate of open field r (a), Dose rate of reference open field (10×10 fields) (b), and Dose rate of blocked field (c) with the block size 10×10 or 4×4 cm

where, T_r is the block transmission for field size r and $D_{block}(r, 10)$ is the dose under the block size 10×10 for field size r in the phantom, we can write S_p factors as,

$$S_p(r) = BSF(r)/BSF(10)$$
$$= \frac{D_{open}(r) \cdot (1-T_r)}{D_{open}(r) - D_{block}(r, 10)} \quad \text{for } r \geq 10\,\text{cm}$$
or
$$= \frac{D_{open}(r)\ (1-T_r)}{D_{open}(10)\ (1-T_{10})} \cdot \frac{D_{open}(10) - D_{block}(10, 4)}{D_{open}(r) - D_{block}(r, 4)} \quad \text{for } r \leq 10\,\text{cm} \cdots\cdots\cdots(6)$$

and S_c factors as,

$$S_c(r) = \frac{D_{open}(r) - D_{block}(r, 10)}{D_{open}(10)\ (1-T_r)} \quad \text{for } r \geq 10\,\text{cm}$$
or
$$= \frac{D_{open}(r) - D_{block}(r, 4)}{D_{open}(10) - D_{block}(10, 4)} \cdot \frac{1-T_{10}}{1-T_r} \quad \text{for } r \geq 10\,\text{cm} \cdots\cdots(7)$$

so, we can measure S_p factor and S_c factor in the phantom with two sets of open field and one set of central blocked (block size 10×10 cm^2 for r≥10 cm, 4×4 cm^2 for r≤10 cm at water surface) fields.

2. Method

0.1 cc (IC-10, Germany) waterproof ionization chamber, electrometer (Capintec, USA) and water phantom (Wellhöfer, Germany) were used. Low melting point alloy was used for fabricating the shielding block as shown in Fig. 1. Measurements are performed for various field sizes at the depth of maximum (dmax) of ^{60}Co gamma ray in the water phantom. The source surface distance (SSD) is 80 cm, the source tray distance (STD) is 53 cm, and the block thickness is 8 cm (1.5% transmission).

RESULT

Table 1. shows the S_c and the S_p factors for ^{60}Co gamma ray. The published and the measured S_c is compared. Maximum deviation is 1.0% and average 0.4%. The results from our new method and published data show good agreement within 1%.

DISCUSSION

The concept of primary and scattered component of a photon beam is commonly used in medical physics. The physical quantity, scatter phantom ratio (SPR) can be utilized to specify the relationship of these two components of the beam and absorbing medium. The S_p factors play important role in this procedure. As the beam energy increases, the size of the chamber buildup cap for in-air measurements has to be increased and it becomes increasingly difficult to calculate the dose in free space from such measurement. Nizin[4,5] and his colleague proposed an idea to obtain primary dose using small attenuator. And the experimental results shows good agreement between the pulished data for ^{60}Co gamma rays. But experimental set up is too complicate to use practically. Kijewski *et al*[6] performed Monte Carlo simulation, Bjärngard *et al*[7] presented analytical approach for separation of primary and scatter component of photon beam. All of these kinds of methods are impractical because of long running time of computer. Our new method does not need complicated experimental setup or long computer running time. Experimental results show accurate values with a small piece of block preparation

CONCLUSION

New measurement method for the S_p and the S_c factors was designed and experimented, we were able to evaluate the S_p factors (or the S_c factors) from the measurements of open field and chamber blocked field which was obtained by placing the central block. The maximum deviation between the published and the measured in this study is 1.0% and average 0.4%. From above findings, we know that equations (6) and (7) are valid for the determination of S_p and S_c in ^{60}Co. For application to the high energy photon beams, we need further studies using linear accelerator.

Table. 1 The S_c and the S_p Factors for Published and the Determined in This Study

Field Size	4×4	6×6	8×8	10×10	12×12	15×15	20×20	25×25	30×30
S_c published	0.949	0.969	0.984	1.000	1.012	1.036	1.062	1.083	1.100
S_p published	0.981	0.987	0.994	1.000	1.006	1.014	1.027	1.037	1.043
S_c determined	0.956	0.979	0.990	1.000	1.016	1.035	1.062	1.077	1.100
S_p determined	0.974	0.977	0.988	1.000	1.002	1.015	1.027	1.043	1.043
deviation (%)	0.7	1.0	0.6	0.0	0.4	0.1	0.0	0.6	0.0

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= 국문초록 =

작은 블럭을 이용한 판톰 내에서의 판톰 산란 인자(Sp Factor)측정법

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판톰 산란 인자(S_p) 측정을 위한 새로운 방법을 소개한다. 측정용 전리함을 가릴 수 있는 블럭을 이용하여 S_p 인자를 구할 수 있음을 이론적으로 증명하였으며, 이의 검증을 위해 ^{60}Co을 이용하여 실험하였다. 이론값과 실험값과의 차이는 1%를 넘지않았다. 이 새로운 방법을 이용하면 고에너지 광자선 측정에서 문제로 대두되고 있는 공기중 측정이 필요 없으며, 작은 블럭 차폐물만을 이용하여 S_p 인자를 구할 수 있음을 확인하였다.