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Variation of effective mass attenuation coefficient at the different location in Mix-Dp phantom.

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ABSTRACT

In order to evaluate radiation exposure of patients in taking a diagnostic radiology, we measured exposure in the Mix-Dp phantom using IONEX ionization chamber and thermoluminescence (TLD) and calculated the values of effective mass attenuation coefficient (effective MAC) from these results. (1) Transmitted dose at broad beam was more greater than that at narrow beam because the former has great amount of scattering, while the latter has extremely small amount of scattering. The value of effective MAC at broad beam was significantly less than that at narrow beam. (2) With enlarged radiation field, depth dose in the phantom increased and the value of effective MAC decreased. The value of effective MAC by depth dose in the phantom was significantly less than that by transmitted dose, although it increased with increasing depth in the phantom. The values of effective MAC by depth dose in the phantom gradually approached to the constant value. However, the values changed according to the size of radiation field. (3) The standard deviation at the measured results with TLD was greater than that with ionization chamber. In conclusion, the method we performed in this study seemed to be very useful in evaluating depth dose and the value of effective MAC.

KEY WORDS

Effective mass attenuation coefficient, Ionization chamber, Phantom, Radiation field

INTRODUCTION

Some authors have reported on radiation exposure of patients in taking a diagnostic radiology[1–5]. However, it is affected by several factors such as the dimensions of patients, the performance of X-ray tube, the size of radiation field, loading factors (tube voltage, current, irradiation time) and so on. Therefore, the standard method of a measuring patient's radiation exposure in taking diagnostic radiology has not been established in spite of every effort. Tamiya et al[1] proposed the calibrations of dosimeter under the national scale. This method is greatly useful in standardizing the values among different institutes in the country. However, the usefulness of calibrating dosimeter is limited to the exposure in air. In order to evaluate a patient's radiation exposure, measurements with a phantom have to be performed. The attenuation in a phantom is related with not only the absorption but also the scattering due to absorber. At the sueface of phantom, most of scattering is backscattering, while at the deep location in the phantom, the scattering within 90° of the scattered angle is added to it. In addition, they are also affected by loading factors, dimensions of patient and the size of radiation field. Since mass attenua-

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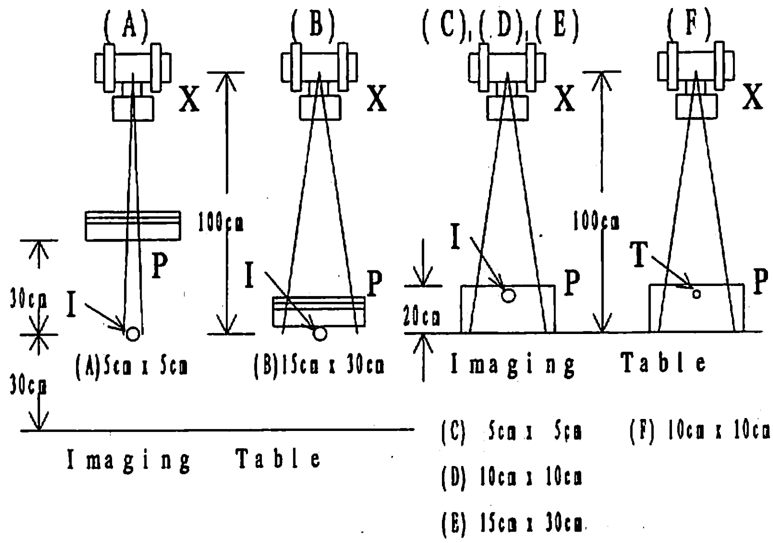

Fig. 1 Geometry in this study.

X, X-ray tube. ; I, IONEX ionization chamber. ; T, Thermoluminescence (TLD). ; P, Mix-Dp phantom. (A) and (B), Measurement of transmitted dose which passed through the phantom using IONEX. (A) narrow beam with 5cm×5cm, and (B) broad beam with 15cm×30cm of radiation field. (C), (D), and (E), Measurement of depth dose in the phantom using IONEX, (C) 5cm×5cm, (D) 10cm×10cm, and (E) 15cm×30cm of radiation field. (F), Measurement of depth dose in the phantom using TLD with 10cm×10cm of radiation field.

tion coefficient (MAC) apparently changes according to the scattering at the difference in the phantom, we defined it as "effective" MAC.

The purpose of this paper is to evaluate effective MAC at the different location in the Mix-Dp phantom and to study radiation exposure and the scattering of X-ray.

MATERIALS and METHODS

A six-peak high-voltage X-ray generator was used. An X-ray tube (CIRCLEX 0.8P38CS, Shimadzu Corp.) has the following dimensions ; 0.8mm×0.8mm of focus size, 12 degrees of target angle, and inherent filtration equivalent to 1.5mm alminum (Al). The beam limiting device (Type R-20) is equivalent to Al of 1.0mm in thickness. The total filtration of X-ray source assembly is equivalent to 2.5mm Al with half-value layer of 2.45mm Al at 80kV of tube voltage. Effective energy was 27.7keV at 80kV.

As a phantom, plates made of Mix-Dp (Kyotokagaku Corp.) with dimensions of 30cm×30cm in area, 5cm in thickness, and 1.01cm^2/g in density were used. The thickness of phantom was chamged from 5cm to 20cm by piling up some sheets of plate. A plate has a groove at the center of the surface where the head of dosimeter was placed. For the comparison, two kinds of dosimeter were used ; 1) IONEX thimble ionization chamber (volume 0.6cc) with calibration factor of 1.200 for Co-60 gamma ray. and 2) thermoluminescence dosimeter (TLD, Kasei Optonix Corp.) made of Mg_2SiO_4 ; Tb with dimensions of 1cm×2mmϕ.

Fig. 1 shows the geometry used in this study. Changing the position of dosimeter and phantom, six kinds of measurement were repeated at 80kV-200mA-0.2sec ; (A)-(F).

(1) The value of effective MAC at the different radiation field

In order to evaluate the effect of beam width, transmitted dose which passed through the phantom was measured in (A) and (B) changing the size of radiation field ; (A) narrow beam with 5cm×5cm of radiation field, and (B) broad beam with 10cm×10cm. In both (A) and (B), focus-to-chamber and chamber-to-table distance were 100cm and 30cm, respectively.

Table 1 Exposure at any distance from the surface of phantom.

Distance from the Surface (cm)	Exposure (mR) in air		Depth Dose (mR) in the Phantom			
	IONEX (A)	IONEX (B)	IONEX (C)	IONEX (D)	IONEX (E)	TLD (F)
0	182.0	197.0	216.320	248.946	253.440	248.946
2	89.0	134.4	145.238	186.900	199.299	167.786
4	46.0	89.0	83.966	122.368	132.935	109.174
6	25.5	59.2	49.405	82.302	88.456	76.837
8	14.0	39.2	29.427	54.684	59.164	52.250
10	8.0	26.8	17.496	36.240	40.176	36.461
12	4.8	17.6	10.580	24.006	26.916	26.436
14	2.8	12.2	6.362	15.390	18.202	16.457

The values of (C), (D), (E), and (F) are normalized at 100cm of distance.

However, in (A) chamber-to-phantom (bottom) distance was 30cm, while in (B) the phantom was placed on the ionization chamber.

(2) The value of effective MAC at the different location in the phantom

In (C), (D) and (E), exposure ("depth dose") at the different location in the phantom was measured changing the size of radiation field. Three kinds of size of radiation field were selected as follows ; (C) 5cm×5cm, (D) 10cm×10cm, and (E) 15cm×30cm on the imaging table. Radiation field of 10cm×10cm was selected as the standard size, 5cm×5cm for the smallest amounts of scattered radiation, and 15cm×30cm based on the examination of thoracic spine. The phantom of 20cm in thickness was placed on the imaging table with 100cm of focus-to-table distance. The position of ionization chamber was changed from 0cm (the surface of phantom) to 14cm in the phantom.

(3) The value of effective MAC using TLD

Measurements in (A) to (E) were performed using IONEX ionization chamber. In order to compare with these results, depth dose in the phantom with 10cm×10cm of radiation field was measured using TLD in (F). The position of TLD was changed from 0cm (the surface of phantom) to 14cm in the phantom.

Taking account of absorption and scattered radiation due to the absorber, the values of effective MAC at the different location in the phantom were corrected by the inverse square law. The result at any position was normalized to the value at 100cm by means of the following equation.

$$E_d = E_x \cdot 100^2 / \{100-(20-X)\}^2 \quad (1)$$

where X (cm) is the distance from the surface of phantom, E_x (mR) is the depth dose at X, and E_d (mR) is the corrected dose. Depth dose was evaluated from the surface of phantom to 14cm in the phantom. Then, the values of effective MAC were calculated by means of the following equation.

$$\mu/\rho = \ln (E_o/E_x)/(x \cdot \rho) \quad (2)$$

where X (cm) is the distance from the surface of phantom, ρ (g/cm^3) is the density of phantom, E_o (mR) is the surface dose, and E_x (mR) is the depth dose at X, and μ/ρ (cm^2/g) is the value of effective MAC.

RESULTS

Exposure were represented with the "mR" unit because of unknown conversion factor from mR to Gy.

(1) The value of effective MAC at the different radiation field

In both (A) and (B), transmitted dose decreased with increasing thickness of phantom. They were less than 10mR in case of more than 10cm in phantom thickness at narrow beam (A). On the other hand, at broad beam (B) they were more greater than those in (A) (Table 1). The values of effective MAC at any thickness in (A) calculated from equation (2)

Table 2 The values of effective mass attenuation coefficient at any distance from the surface of phantom.

Distance from the Surface (cm)	Effective Mass Attenuation Coefficient (cm^2/g)					
	in air		in the Phantom			
	IONEX (A)	IONEX (B)	IONEX (C)	IONEX (D)	IONEX (E)	TLD (F)
2	0.3541	0.1893	0.1972	0.1419	0.1190	0.1953
4	0.3404	0.1967	0.2342	0.1758	0.1597	0.2040
6	0.3243	0.1984	0.2437	0.1826	0.1737	0.1940
8	0.3174	0.1998	0.2469	0.1876	0.1801	0.1932
10	0.3094	0.1975	0.2490	0.1908	0.1834	0.1902
12	0.2999	0.1993	0.2490	0.1930	0.1850	0.1850
14	0.2952	0.1967	0.2494	0.1967	0.1863	0.1921

decreased with increasing thickness of phantom, while the values in (B) increased with increasing thickness (Table 2).

(2) The value of effective MAC at the different location in the phantom

In (C), (D), and (E), depth dose decreased with increasing depth in the phantom. At the same depth in the phantom, they increased with increasing size of radiation field (Table 1). The values of effective MAC increased with increasing depth in the phantom. At the same depth in the phantom, they decreased with increasing size of radiation field (Table 2). Fig. 2 shows the values of effective MAC with the different radiation field. As shown in Fig. 2, these values gradually approached to the certain constant value with increasing depth. However, the constant values differed among the different size of radiation field.

(3) The value of effective MAC using TLD

Depth dose measured by means of TLD were approximately similar with those in the measurement (D) by ionization chamber (Table 1, 2).

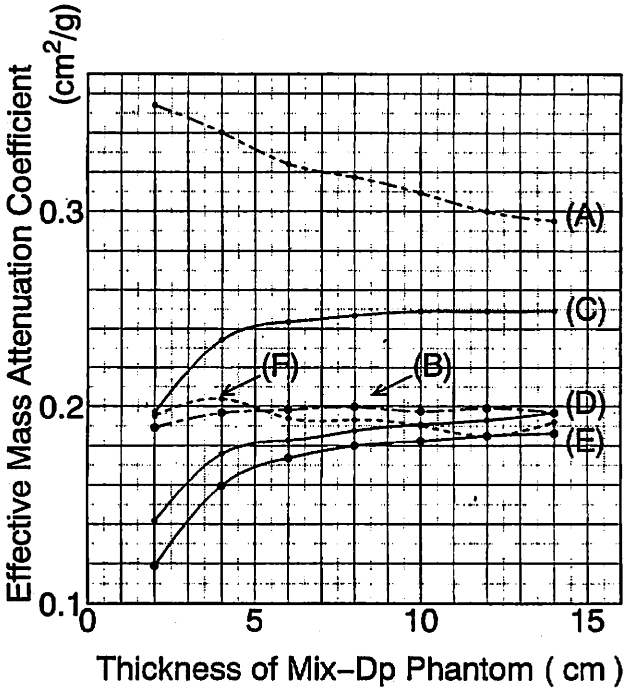

Fig. 2 The values of effective mass attenuation coefficient at any depth in the phantom.
(A) and (B), Measurement of transmitted dose which passed through the phantom using IONEX, (A) narrow beam with 5cm×5cm, and (B) broad beam with 10cm×10cm of radiation field. (C), (D), and (E), Measurement of depth dose in the phantom using IONEX, (C) 5cm×5cm, (D) 10cm×10cm, and (E) 15cm×30cm of radiation field. (F), Measurement of depth dose in the phantom using TLD with 10cm×10cm of radiation firld.

DISCUSSION

It is well known that X-rays are composed of the continuous spectrum of energy. If it has single energy, the value of effective MAC will be easily evaluated. When the scattering has to be considered, multiplication of the buildup factor is alone needed to get satisfactory results. In the estimation of X-rays quality, for simplification, the concept of effective energy is usually employed where X-rays with continuous energy are substituted for the radiation with single energy. However, this concept has the disadvantage that X-rays are estimated totally and roughly. Therefore, it is not so useful in estimating exposure at any location in the subject regionally and exactly.

Next problem in considering X-rays quality is the absorption. X-rays quality changes according to the thickness of patients or phantom. It is generally said that thickness of the second half-value layer is greater than that of the first one. X-rays with long wavelength interacts at the superficial layer in the absorber, and therefore the attenuation increases in appearance. On the other hand, X-rays with short wavelength increases at the deep layer and the attenuation decreases as a result of increasing transmitted dose which passed through the absorber. In this study transmitted dose was relatively greater than depth dose in the phantom. The difference mainly depends on the absorption.

The problem of the scattering plays the most important role in considering X-rays quality. Smaller radiation field is enough to calibrate dosimeters. However, in order to evaluate depth dose in the human body, the scattering has to be considered. In this study, significant difference of transmitted dose between narrow and broad beam was shown. The difference was caused by the scattering. Because there is extremely small amount of scattering at narrow beam, while greater amount at broad beam. Depth dose in the phantom with enlarged radiation field was greater than that with shrinked radiation field owing to the scattering. Therefore, it may be much better to measure depth dose in the enlarged radiation field.

The value of effective MAC by depth dose in the phantom was fairly less than that by transmitted dose. The value of effective MAC decreased as the size of radiation field increased, while it increased with increasing depth in the phantom. This suggests that the effect of the scattering is greater than that of attenuation in X-rays with low energy. As shown in Fig. 1, the value of effective MAC by depth dose in the phantom gradually approached to the certain constant value.

In the measurement of depth dose, it is desirable to use dosimeter with small measuring volume. The TLD satisfies this demand. However, it also has the disadvantage that the measurements using TLD depend greatly on the enetgy and the standard deviation on the results is remarkably greater than that by ionization chamber. Also in this study considerable variation was shown in the value of effective MAC by means of TLD.

It appears that X-rays with different quality occur between single- and three-phase generators and between different total filtration. Although the estimation of the scattering using the Monte Carlo method was tried, the standard method in evaluating depth dose in the subject has not been established. Therefore, our method performed in this study appeared to be very useful in evaluating depth dose.

In conclusion, we propose that it is very useful in evaluating radiation exposure to measure depth dose in the phantom by means of ionization chamber and calculate the value of effective MAC in taking a diagnostic radiology.

REFERENCES

1) Tamiya, T., et al. : Evaluation of patient exposure resulting from diagnostic radiology examinations. Report 1 : dosimeter calibrations. Bull. Nagoya Univ. Coll. Med. Tech., 4 : 49-54, 1992.

2) Kato, H. : Analysis of scattered radiation in an irradiated body by means of the Monte Carlo simulation- Scatter-primary dose ratio-. Jpn. J. Radiol. Technol., 43 : 1513-1518, 1987.

3) Miyake, H., et al. : Dose distributions at standard diagnostic X-ray energy. Bull. Sch. Health Sci. Okayama Univ., 2 : 63-71, 1991.

4) Nakamura, M., et al. : Spectal analysis of scarrered radiation in diagnostic X-rays. Jpn. J. Radiol. Technol., 48 : 1815-1822, 1992.

5) Takada, Y., et al. : Measurement of distribution at medical X-ray diagnosis. Jpn. Associ. Radiol. Technol., 41 : 524-529, 1994.

照射野の大きさとファントムの厚さによる見かけ上の質量減弱係数の変動

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要　旨

放射線診断に伴う放射線被曝を評価するため，IONEX 電離箱と熱ルミネセンス線量計を用いて被曝線量を測定し，これらの値から見かけ上の質量減弱係数（MAC）を計算した。(1) 照射野の幅に対する見かけ上の MAC の違いについて，細い線束と広い線束では有意な差があり，前者は散乱が全くないか小さく，後者は散乱が多かった。(2) ファントム内における違いについては，照射野が広くファントム内を通過したものとそうでないものとに違いがあった。ファントムを通過した透過線量から計算した見かけ上の MAC は次第に一定値に近づくように見えた。一方，ファントム内の深部線量から計算した見かけ上の MAC については変動が大きかった。けれども，見かけ上の MAC はファントムの深さが増せば大きくなった。ファントム内の深部線量から計算した見かけ上の MAC は一定値に収束したが，同じ一定値ではなかった。照射野の幅が大きくなるにつれ見かけ上の MAC は小さくなった。(3) TLD を用いて測定したとき標準偏差が電離箱より大きくエネルギーにおおきく依存していたので利用価値が少なかった。したがって，本研究に用いた方法で深部線量を評価することが必要である。