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Evaluation of Scattered Radiation During Taking Plain Radiographs

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ABSTRACT

Scattered radiation, occurring in X-ray radiography was studied both in experiments using a humanoid phantom and in clinical practice. The results showed that the dose measured with the phantom placed on a wooden imaging bed was about twice of that without the phantom at the exposure conditions of 120KVp-100mA or 200mA and 80KVp-300mA. The dose, with the change of detector-to-ground distance(DGD), increased remarkably above 75cm, but slightly below 50cm. The maximum dose of 271μR, 563μR was measured without the phantom in place and 561μR, 1110μR with the phantom at the exposure time of 0.1, 0.2sec, respectively. Dose distribution around the X-ray tube was not uniform with the phantom, while it was uniform without the phantom. Dose was effected by the rotation of the phantom and the maximum dose was measured at 45° of rotating angle. Similar results were also shown in X-ray radiographies of 14 patients. The dose measured during taking radiograph of a patient was about twice of that without patient present. It was shown a linear relation between the dose and mAs value. There were no significant differences among the doses measured from three directions of anteroposterior (AP), right (RAO), and left anterior oblique (LAO). However, dose increased significantly for the lateral view of radiograph.

KEY WORDS

Scattered radiation, Dose, Humanoid phantom, Radiography, mAs

INTRODUCTION

In the use of various modalities with X-ray generator system, concern has always been given to the reduction of harmful radiation exposure to the patients and technologists[1),2),3)]. Since the scattered radiation not only degrades the imaging quality but also increases the radiation exposure, it is important to make every effort to reduce it as low as possible. In previous reports[4),5)], we have described the effects of exposure condition and imaging table on scattered radiation. The scattered radiation dose increased with the increases of tube voltage, current, exposure time, and field size. However, it decreased markedly with the increase of distance from the X-ray tube. When a wooden imaging table of 70cm in height was used, dose increased above 80cm, while it decreased below 70cm because of the shielding effect of the table.

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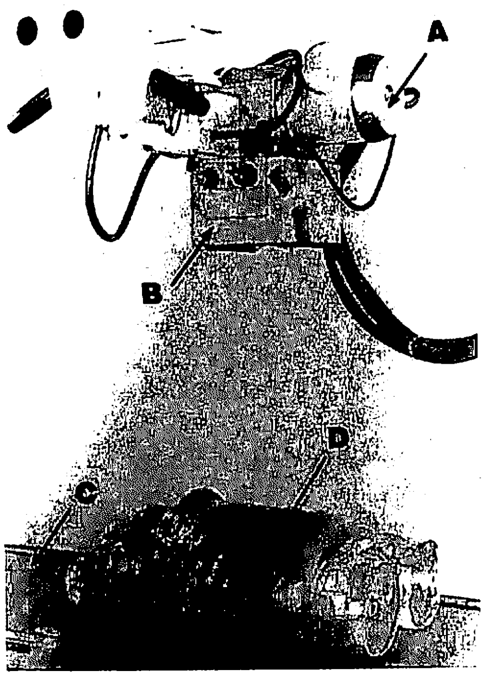

Fig. 1 A photograph of X-ray apparatus.
A : X-ray tube, B : Collimeter, C : Imaging table, and D : Humanoid phantom.

Fig. 2 A photograph of humanoid phantom.

The purpose of this paper was to evaluate the scattered radiation during taking plain radiographs in clinical practice. In order to reduce the unnecessary exposure to the patient, a second radiography for the same patient was avoided. Therefore, detailed evaluation was performed in the experiment using a humanoid phantom.

MATERIALS AND METHODS

1. Experiments using the humanoid phantom

1) MATERIALS

As shown in Fig. 1, X-ray apparatus with an X-ray tube (CIRCLEX 1/2 U10CN-25, Shimazu Corp., Kyoto), and a collimeter (R-10 type) was used in the imaging room, whose size was 550×510×340cm (height)[4]. The center of the X-ray tube was at 184cm from the nearest wall of the imaging room, at 263cm from the other wall, and at 170cm vertically from the ground. The axis of the X-ray tube was always kept parallel to the nearest wall.

A wooden imaging table with dimensions of 200×67×70cm (height) was installed in such a way that the center of it was always consistent with that of the X-ray tube[5]. The distance from the focus to the surface of the imaging table was 100cm.

A humanoid phantom (SB-2-A type, Kyotokagaku Corp.) with dimensions of 63cm in height, 92cm around the breast, 70cm around the waist, and 85cn around the hip was used (Fig. 2). The phantom wa made from acrylic acid resin including actua human bones and cork in place of the lung. Th phantom was placed on the imaging table (Fig. 1

For the measurement of doses, a detector witl an ionization chamber (Model 660, Victoreen Corp USA) was used. The detector only gave the mR unit instead of SI units. The results of survey meter read ing were not converted to SI units, although it wa recommended by the international Commission o Radiation Units and Measurements (ICRU).

2) METHODS

In order to represent dose distribution around a X-ray tube, polar coordinate was adopted, wher the anode and the cathode of the X-ray tube wer determined to be 0° and 180°, respectively. Th cranial direction of the phantom located at 180 A radiation field of 44×44cm in size on the imagin table was determined. Routine measurements c dose were performed at 100cm of the vertic detector-to-ground distance (DGD), and the horizo tal focus-to-detector distance (FDD). In every stud comparison of doses between the conditions of wit or without using the phantom were made.

(1) Effects of exposure condition

Exposure conditions of 120KVp-100mA or 200m and 80KVp-300mA were selected because they are the conditions in clinical practice for taking plain chest and abdominal radiographs, respectively. Measurements were performed at 270° on the polar map.

(2) Effects of DGD

To evaluate the effect of DGD on the scattered radiation, doses at various DGD from 15cm to 135cm were measured at 270° on the polar map

(3) Dose distribution around the X-ray tube

Doses around the X-ray tube were measured circumferentially at 30° interval under 80KVp-300mA-0.1sec or 0.2sec condition.

(4) Rotation effect of the phantom

Doses were also measured at 80KVp-300mA-0.1sec or 0.2sec while rotating the phantom from −90° to 90° at 15° interval, The right, the left lateral, or the anteroposterior (AP) view in clinical practice were obtained at the angle of −90°, 90° or 0°, respectively. Furthermore, the left (LAO), or the right anterior oblique (RAO) view was obtained at the positive or the negative angle, respectively.

2. Measurements of dose in clinical practice

1) MATERIALS

The X-ray apparatus with an X-ray tube (CIRCLEX 0.3/0.8 P38C, Shimazu Corp.), a collimeter (R-20 type), and a phototimer (Model SP7-070) was employed. A Bucky-Potter table and a Lieders cassette holder were installed in the imaging room with dimensions of 350×520×350cm (height). The Bucky table with dimensions of 78×200×60cm (height) was fixed at the position where the center of it was 120cm from the nearest wall, and 230cm from the other wall. The upper plate of the Bucky table was made from plastics. The Lieders cassette holder located at 220cm from the center of the Bucky table along its longitudinal axis, and at 10cm in front of wall. For the measurement of doses the same detector was used.

Fourteen adult patients were selected at random : 4 for the chest radiography, 6 for abdominal radiography, and 4 for the lumbar vertebral radiography.

2) METHODS

At 270° on the polar map measurements of doses were performed at a fixed distance 100cm for FDD and DGD. Prior to the exposure, appropriate exposure time was selected empirically. Exposure time was automatically controlled by the phototimer and was indicated in units of milliampere seconds (mAs)[6]. After the radiography of each patient, actual exposure time was calculated from the following formula :

Exposure time (sec)=mAs/Current (mA) ······(1)

According to the calculated exposure time, a second radiography was made without the patient present and the data were compared between these two situations.

(1) Chest radiography

Using the Lieders cassette holder, posteroanterior (PA) view of patient was taken on the erect position with 200cm of focus-to-film distance (FFD). Focus-to-ground distance (FGD) was changed according to a patient's height. A radiation field of 35.6cm (14inch)×35.6cm was determined according to film size. Exposure condition of 120KVp-200mA was used.

(2) Plain abdominal or lumbar vertebral radiographies

The anteroposterior (AP) view of abdomen or lumbar vertebrae was taken with 120cm of FFD while the patient lying on the Bucky table at the supine position. In lumbar vertebral radiography, the right lateral view and the oblique views, such as LAO and RAO, were added. A radiation field of 35.6cm×43.2cm (17 inch) was determined according to film size. The exposure condition of 80KVp-300mA was usually used for AP, LAO, and RAO views. However, the exposure condition of 90KVp-300mA was used for the right lateral view.

RESULTS

1. Experiments using the humanoid phantom

1) Effects of exposure condition (Table 1)

The result showed that no matter what exposure condition was used, the doses measured with the phantom were usually twice of that without the phantom.

2) Effects of DGD (Fig. 3)

It was observed that the scattered radiation increased only slight when the DGD was below 50cm, while it increased greatly when the DGD above 75cm. A maximum dose of 271μR, 563μR was measured without the phantom and, 561μR, 1110μR with the phantom at exposure time of 0.1, 0.2sec,

Table 1 **Comparison of dose between without and with the phantom : Effects of exposure condition. Measurement at 100cm of FDD and DGD, and 270° on the polar map.**

Volt (KVp)	Current (mA)	Time (Sec)	Dose 1 (μR)	Dose 2 (μR)	Ratio (Dose 2/ Dose 1)
120	100	0.02	42	83	1.98
120	100	0.03	92	181	1.97
120	100	0.04	117	232	1.98
120	200	0.02	113	239	2.12
120	200	0.03	225	452	2.01
120	200	0.04	281	546	1.94
80	300	0.02	43	88	2.05
80	300	0.03	94	184	1.96
80	300	0.04	120	254	2.12
80	300	0.10	271	561	2.07
80	300	0.20	563	1087	1.93

Dose 1 : Dose without phantom
Dose 2 : Dose with phantom

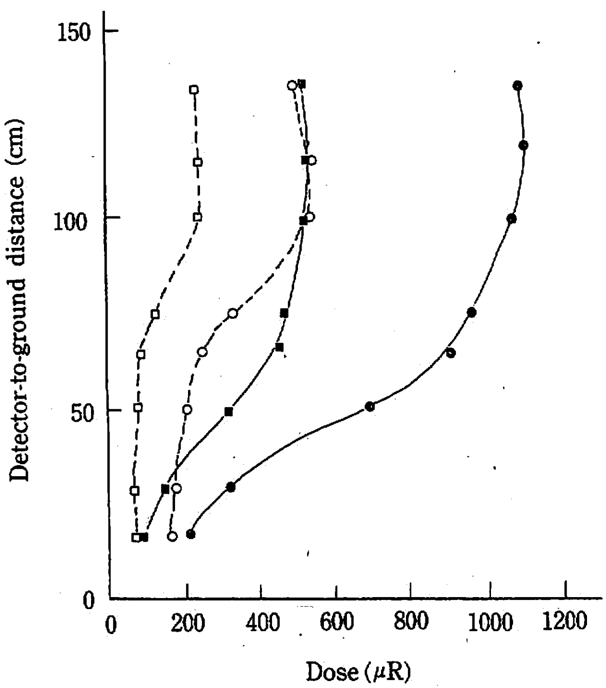

Fig. 3 **Comparison of dose between without and with the phantom at 80KVp-300mA-0.1sec and 0.2sec.**
● ; 0.2sec with the phantom, ■ ; 0.1sec with the phantom, ○ ; 0.2sec without the phantom, □ ; 0.1sec without the phantom.

respectively. There was no further increase of dose observed while the DGD was above 100cm.

3) Dose distribution around the X-ray tube (Fig. 4)

Without the phantom, dose distribution was uniform circumferentially around the X-ray tube. However, dose distribution was not uniform with the phantom. There was no increase of dose at 0° on the polar map. Similar curves were obtained at 0.1, and 0.2sec of exposure time, although dose at 0.2sec was about twice of that at 0.1sec.

4) Rotation effect of the phantom (Table 2)

A maximum dose of 656μR, 1370μR was measured at the rotating angle of 45° for 0.1, 0.2sec, respectively. Dose ratio of 45° to 0° was 1.17, 1.26 for 0.1, 0.2sec, respectively.

Table 2 **Effects of the rotation of the phantom**

AGL (°)	0.1sec Dose (μR)	0.1sec Ratio	0.2sec Dose (μR)	0.2sec Ratio
	271*		563*	
0	561	2.07	1087	1.93
30	591	2.18	1300	2.31
45	656	2.42	1370	2.43
60	634	2.34	1340	2.38
90	550	2.03	1140	2.02
−30	583	2.15	1230	2.18
−45	604	2.23	1250	2.22
−60	532	1.96	1140	2.02
−90	537	1.98	1130	2.01

AGL : Rotating angle of phantom
* : Dose without phantom

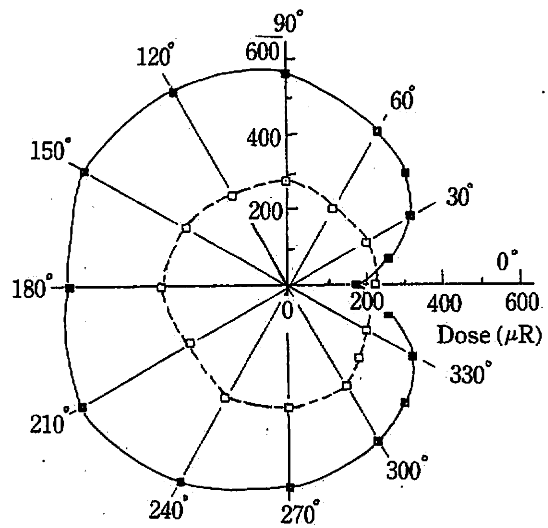

Fig. 4 **Dose distribution around the X-ray tube at 800KVp-300mA-0.1sec**
■ ; with the phantom, □ ; without the phantom.

Table 3 Dose during taking abdominal radiographs.

View	Volt (KV_p)	Cur (mA)	Time (mAs)	Dose 1 (μR)	Dose 2 (μR)	Ratio (Dose 2/Dose 1)
AP	80	300	34	220	405	1.84
AP	80	300	40	219	484	2.20
AP	80	300	45	308	500	1.62
AP	80	300	60	402	971	2.42
AP	80	300	75	470	1040	2.21
AP	80	300	80	520	1320	2.54

AP : Anteroposterior view
Dose 1 : Dose without a patient Dose 2 : Dose with a patient

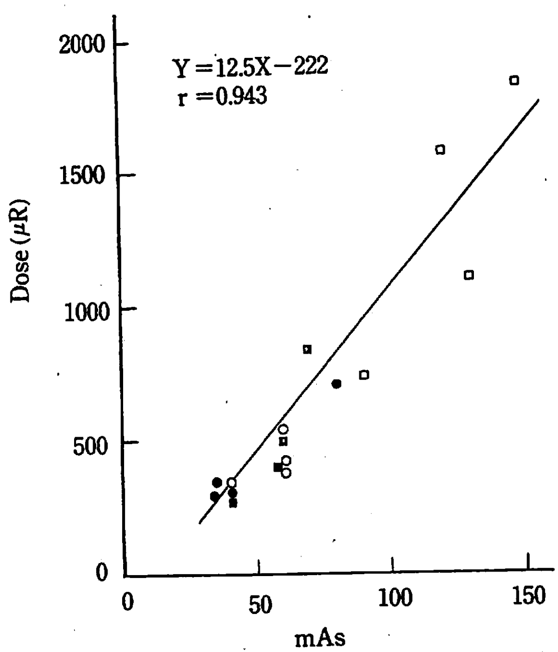

Fig. 5 Correlation between mAs and dose during taking a radiograph of the lumbar vertebrae.
● ; Anteroposterior, ○ ; Right anterior oblique, ■ ; Left anterior oblique, □ ; Right lateral

2. Measurements of dose in clinical practice

1) Chest radiography

A scattered radiation of 5, 14μR was measured at 120KVp-200mA-6mAs, or 8mAs in two patients, respectively. However, in other two patients, the scattered radiation was undetectable.

2) Abdominal radiography (Table 3)

As shown in Table 3, scattered radiation increased from 405μR to 1320μR when the mAs value increased from 34mAs to 80mAs.

3) Lumbar vertebral radiography (Fig. 5)

Doses increased linearly with the increase of mAs value. The correlation coefficient between mAs value and dose was 0.943. The formula was expressed as "Y=12.5X-222", where X and Y represent mAs value and dose, respectively. Among three views of AP, RAO, and LAO, significant difference of scattered radiation dose was not observed. However, doses increased markedly for the lateral view.

DISCUSSION

In the experiment using the humanoid phantom, scattered radiation doses increased to about twice as compared with that of without using the phantom. This was also observed in clinical practice. In other words, during clinical radiography with the patient present it generates two times more scattered radiation compared with that without the patient present. However, this scattered radiation increased in a different manner when the DGD was divided into two parts. One is above the table, where doses increased markedly. Another one is below the table, where dose increased slightly. It was believed that the scattered radiation was shielded by the table[5]. In spite of uniform dose distribution around the X-ray tube without the phantom, dose distribution was not uniform with the phantom. The scattered radiation was not increased in the region from -15° to 15° on the polar map. The reason was unknown. A further study should be performed to investigate the effects of phantom size, shape, or positioning and so on. The maximum dose was measured at the rotating angle of 45°, although significant difference of dose was not shown among different rotating angles. Since scattered radiation occurs when there exists anything on the way through which the X-ray beam passes, it seems to be reasonable that the maximum dose was measured at the rotating angle of 45°. However, in clinical practice, the scattered radiation increased linearly with the increase of mAs value and increased for the lateral view significantly, compared with the other views of AP, RAO, and LAO. A large mAs and high tube voltage are needed in the lateral view because of the thickness of a patient's body. Therefore, it was considerable that scattered radiation was more effected by the exposure condition, such as mAs or tube voltage, than by the rotating angle of the phantom or a patient.

In conclusion, radiological technologists should consider protecting themselves from radiation exposure when they manage X-ray generator system. Therefore, it is very important for them to know the scattered radiation from an X-ray apparatus in their institutes.

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単純X線写真撮影時の散乱線の評価

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要　旨

単純X線写真撮影時に発生する散乱線について，人体模型を用いた実験と臨床により検討した。模型使用時の散乱線は，使用しない時の約2倍に増加した。高さ70cmの撮影台を使用したので，75cm以上の高さでは線量は著明に増加したが，50cm以下では線量の増加は僅かであった。X線管周囲の線量分布は，模型を使用しない時にはほぼ均一であったが，使用時には不均一となり，陽極側では線量の増加が認められなかった。模型の回転による影響では，45°回転させた時に最大線量を示した。14人の患者を対象とした臨床的検討でも同様な結果が得られ，被写体がある時の線量は，ない時の約2倍に増加した。線量は撮影時のmAsの増加につれ直線的に増加した。腰椎の撮影では，正面と斜位像の間で線量に大きな差は認められなかったが，側面像では明らかに増加した。