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Evaluation of the reduction effect of scattered radiation by various grids.

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種々のグリッドによる散乱線の除去効果

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要　旨

x線撮影において，高電圧，高被写体厚の条件のもとに撮影を行うと，散乱線が多く発生する。散乱線はx線写真のコントラスト，解像度等を低下させるので，診断に適したx線写真を得るためには，条件に応じたグリッドを選択し，散乱線を除去することが重要である。グリッドの性能を比較するために，蛍光量計，線量計（2種）を用いて，一次x線透過率，全x線透過率，散乱線透過率を測定し，選択能，コントラスト改善能，ブッキイ係数および除去効率等を算出することにより，散乱線除去効果について評価した。グリッドの使用に際しては，それぞれの撮影条件による使い分けを行ったり，x線の線質や被爆線量等も考慮のうえ，総合的に決定するのが望ましい。

ABSTRACT

In order to reduce scattered radiation and to obtain high quality of radiographic images, various grids have been used widely. The performances of five grids were examined at 55, 80, and 95KVp-100mA-0.2sec using a water phantom (18cm in depth). The absorption coefficient (μ) of water decreased with increasing tube voltage and the reduction effect of scattered radiation has been suggested to be energy dependent. Radiation (Dos) dividing primary radiation (Tp), total radiation (Tt), and scattered radiation (Ts) was estimated using a fluorescent value (F) by a fluorescent meter. Simultaneously it was estimated by X-ray dose meters. Dos and F decreased proportionally with increasing grid ratio and density (lines/cm). Dos and F increased markedly with increasing tube voltage. Though considerable agreement was observed between Ip, It, and Is values by a fluorescent meter and these by X-ray dose meters, good correlation was not observed between Σ, K, and B values by a fluorescent meter

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and these by dose meters. The reduction effect by a grid was more effective on Ts than Tp and Tt. Absorption ratios of radiation by grids decreased with increasing tube voltage. It can be used conveniently in evaluating the reduction effect.

INTRODUCTION

X-ray imagings have been rapidly advanced in the medical science and technical engineering since the beginning of this century. Many efforts were performed to obtain clear contrast images in diagnostic radiology. When a radiation beam passes through a substance, radiation is deviated in the different directions. Consequently, scattered radiation occurs. The occurrence of scattered radiation deteriorates the image quality of radiography, so that the reduction of scattered radiation is one of the most important means to improve the image quality. In order to reduce scattered radiation, a variety of grids are usually employed. Interspacers, which are laid between lead strips, are made of different materials such as aluminum, plastics, and wood. By changing the thickness of lead strips and interspacers, different grid ratios and densities are obtained. By changing the arrangement of lead strips, parallel, cross, bucky, and focus grids are formed. Thus, different grid ratios, densities, and focal distance determine the characteristics of grids at various conditions. Therefore, appropriate grid should be selected according to patient size, positioning and so on. Though some reports 1)-4) were published on the grids, the reduction effect of scattered radiation using a dose meter was not previously reported. The purpose of this paper is to evaluate the reduction effect of scattered radiation by various grids.

MATERIALS AND METHODS.

1. X-ray generator system.

The X-ray apparatus was consisted of the combination of the X-ray tube, manufactured by Hitachi company (Japan) and the equipment except the X-ray tube, manufactured by Shimazu company (Japan). The rotating anode in the X-ray tube has tungsten target with 18 degrees of angle. X-ray beam is shielded by lead, except a collimator hole.

2. Grids and a phantom.

Five kinds of grids containing parallel, focus, bucky, and cross grids were examined for this study. These are made in layers of lead strips and aluminum interspacers with 5/1, 6/1, 8/1, (8/1), and 10/1 of grid ratio (R) and with 23, 26, and 34 of density (lines/cm) (Table 1).

As a water phantom, water was filled 18cm in a container of acrylics.

Table 1. Grids charactristics.

No	Grid Ratio	Grid Density/cm	Focal Distance(cm)	Inter Spacer
1	5/1 parallel	26	∞	Al
2	6/1 parallel	34	150-∞	Al
3	8/1 focus	34	100	Al
4	(8/1)bucky	23	100	Al
5	10/1 cross	34	100	Al

3. Measuring instruments and arrangement.

The exposure was measured by two methods using a fluorescent meter (Alco electric CO, Japan) and two X-ray dose meters. The former makes use of a fluorescent screen and a photomultiplier. The screen in the detecting part belongs to FS type and transforms exposure into fluorescence. The latter was performed using a digital radiation dose meter (Model 660 of ionization-chamber type), and a integrally-mounted ionization chamber (Model 06-525 of "RAD-CHECK"). Both instruments were manufactured by Victoreen company (USA). Models 660 and 06-525 were used in cases of low and high dose respectively. In Model 660, total exposure mode was chosen to record total exposure per exposure. The manufacturer's specification describes that 0.001mR to 9.9mR of scale reading is possible. In case of more than 2mR, Model 06-525 was used. In Model 06-525, the exposure reading ranges 0.01 to 1.99R with digital display. Fluorescent value (F) and X-ray dose (Dos) were estimated by a fluorescent meter and a dose meter at the same time respectively.

Being far away 100cm vertically from a x-ray focus, two detectors were set within the field of primary beam, with 2cm of grid-to-detector distance. The phantom-to-grid distance was changed from 2 to 65cm, in case of 100cm of focus-to-grid distance (Fig 1).

4. Measurements and calculations.

(A) Absorption coefficient (μ) of water under the varius exposure conditions.

Absorption coefficient of water was calculated by the following formula,

$$I=I_0 \exp^{(-\mu x)}. \qquad \text{——(1)}$$

where I_0 and I are exposure dose before and after water phantom (mR) respectively, x is water thickness (18cm) and μ is absorption coefficient of water (cm^{-1}). The I_0 and I were measured at 55, 80 and 95KVp.

(B) Various parameters of grid performance.

In order to evaluate the effect of tube voltage, it was changed 55, 80 to 95KVp at 0.2sec of exposure time and 100mA of current. Fifty-five, 80 and 95KVp of tube voltage are based on the photography taken at low, medium and high voltage respectively.

1). Measurements for transmission of primary radiation, Tp (Tp=Ip'/Ip").

Tp is defined as Ip'/Ip", where Ip' is the value of primary radiation with grid and Ip" is that without grid ("non grid"). Measurements were repeated at 65cm of phantom-to-grid distance in Fig. 1A.

2). Measurements for transmission of total radiation, Tt (Tt=It'/It").

Tt is defined as It'/It", where It' is the value of total radiation with grid and It" is that without grid. Measurements were repeated at 2cm of phantom-to-grid distance, without the lead shield in Fig. 1B.

3). Measurements for transmission of scattered radiation, Ts (Ts=Is'/Is").

Scattered radiations were measured when the meters were shielded from all primary radiation by the lead shield. Ts is defined as Is'/Is", where Is' is the value of scattered radiation with grid and Is" is that without grid.

Measurements were repeated at 2 cm of phantom-to-grid distance, with the lead shield in Fig. 1B.

4). Selectivity (Σ), Contrast improvement ratio (K), and grid exposure factor (Bucky factor: B).

These parameters are derived from the following formulas and represent the performance of grids.

$$\Sigma = Tp/Ts. \quad \text{——(2)}$$

$$K = Tp/Tt. \quad \text{——(3)}$$

$$B = It''/I't = 1/Tt. \quad \text{——(4)}$$

5). Absorption ratio of grids.

Absorption ratios by grids were calculated using Tp, Tt and Ts. Mean values of

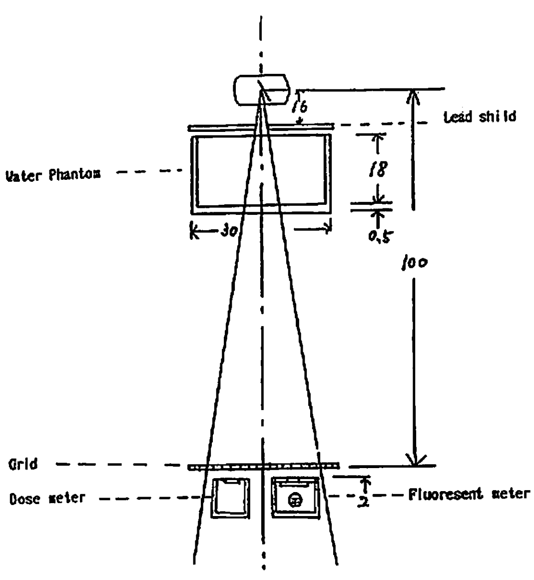

Fig. 1A Arrangement (Case of Tp)

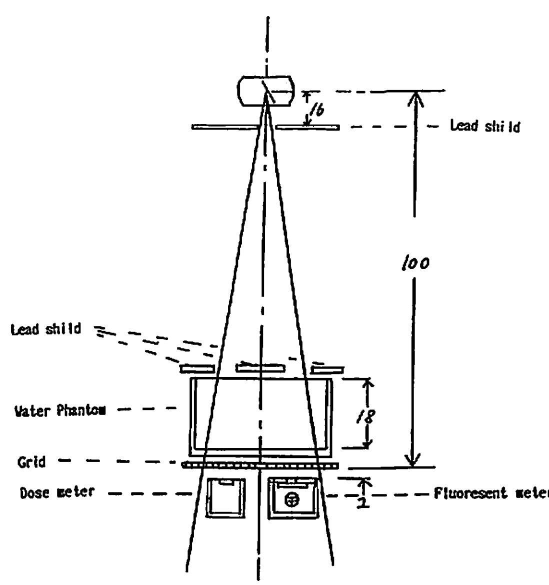

Fig. 1B Arrangement (Case of Tt and Ts)

at least three measurements were used as the results.

RESULTS

(A) Absorption coefficient (μ) of water under the varius exposure conditions (Table 2).

The value of μ decreased with increasing tube voltage. At the same kVp, the μ by Dos were higher than that by F.

(B) Various parameters of grid performance.

1). Values of Tp (Table 3).

In case of both F and Dos, Ip' and Ip" increased exponentially with increasing tube voltage (Fig. 2).

Though every Dos-lines have same slope, F-lines have different slopes in hemilogarithm. The difference of F value at high KVp is smaller than that at low KVp. More than 1 of F at 55KVp was so observed at 5/1 alone in Fig. 2 that grid is not required at 55KVp. Similarly, less than 3 of Tp value at 80KVp was observed at 10/1 alone in Fig. 2. In other cases at 80KVp, Tp value was more than 3.

Table 2. The absorption coefficient of water at 55, 80, and 95KVp of tube voltages in case of 0.2sec of exposure time.

volt (KVp)	non phantom F	non phantom Dos	18cm phantom F	18cm phantom Dos	μ (cm^{-1}) F	μ (cm^{-1}) Dos
55	460	154	5.77	0.70	0.243	0.299
80	1060	291	22.0	3.40	0.215	0.247
95	1480	376	40.7	8.30	0.200	0.212

Table 3. Values of Tp, Tt and Ts at 55, 80 and 95KVp-100mA-0.2sec-18cm in depth.; Tp=Ip'/Ip", Tt=It'/It", Ts=Is'/Is".

volt KVp	grid ratio	Tp F	Tp Dos	Tt F	Tt Dos	Ts F	Ts Dos
55	5/1	0.51	0.61	0.36	0.28	0.15	0.17
	6/1	0.44	0.45	0.24	0.13	0.09	0.15
	8/1	0.24	0.38	0.18	0.13	0.05	0.07
	(8/1)	0.54	0.54	0.24	0.20	0.07	0.14
	10/1	0.25	0.31	0.10	0.09	0.03	0.05
80	5/1	0.46	0.68	0.57	0.37	0.25	0.24
	6/1	0.57	0.52	0.36	0.18	0.14	0.19
	8/1	0.38	0.44	0.29	0.17	0.09	0.11
	(8/1)	0.62	0.56	0.34	0.24	0.10	0.16
	10/1	0.42	0.38	0.18	0.14	0.06	0.08
95	5/1	0.68	0.72	0.64	0.30	0.27	0.28
	6/1	0.58	0.53	0.39	0.15	0.15	0.22
	8/1	0.35	0.47	0.32	0.14	0.09	0.13
	(8/1)	0.57	0.56	0.36	0.18	0.11	0.18
	10/1	0.43	0.41	0.21	0.12	0.07	0.09

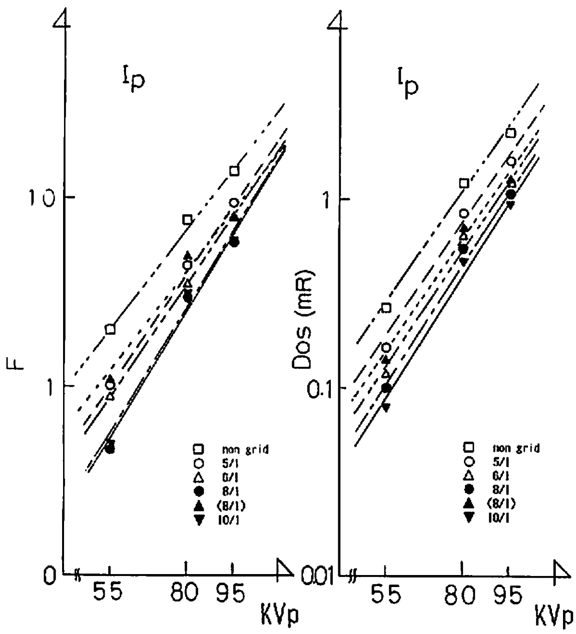

Fig. 2 Values of Ip

2). Values of Tt (Table 3).

In case of both F and Dos, It' and It" increased exponentially with increasing tube voltage (Fig. 3).

3). Values of Ts (Table 3).

In case of both F and Dos, Is' and Is" increased exponentially with increasing tube voltage (Fig. 4).

Every lines, except bucky F-line, have same slope in hemilogarithm.

4). Values of Σ (Table 4, Fig. 5).

Values of Σ by both F and Dos decreased with increasing tube voltage. In case of F, values of Σ increased with increasing grid ratios. In case of Dos, 6/1-grid ratio had the minimum value of Σ.

5). Values of K (Table 4, Fig. 6).

K values by F decreased slightly with increasing tube voltage. In case of both F and Dos, value of K didn't have a constant relation with grid ratio.

6). Values of B (Table 4, Fig. 7).

B values by F decreased markedly with increasing tube voltages. In case of both F and Dos, values of B increased with increasing grid ratio, except bucky grid.

From the results of 4)-6), the Σ, K, and B values increased with increasing grid ratios at the constant voltage. The 10/1-grid ratio had the maximun value. The grid

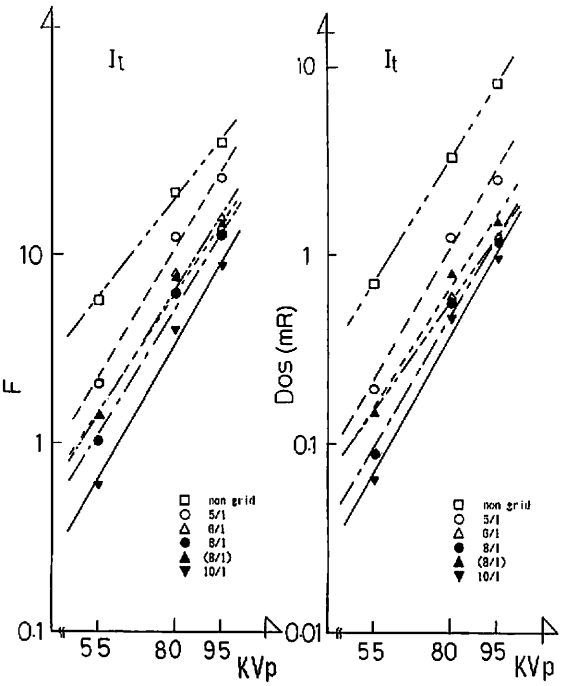

Fig. 3 Values of It

with a high density had large reduction effect.

7). Absorption ratio of grids (Table 5).

Absorption ratio of radiation by grids decreased with increasing tube voltage. Absorption ratio at high grid ratio was inclined to be higher than that at low grid ratio.

DISCUSSION

Since scattered radiation deteriorates the image quality of radiography, it is very important to prevent scattered raditation in photography. Some references[1),2)]describe how to measure scattered radiation. However, the measuring result of scattered radiation has been not published.

In the present study, measurements were performed at 55, 80, and 95KVp. The exposure condition of 55, 80, and 95KVp are based on the photographies taken at low, medium and high voltages. ICRU's report[3)]describes that 100KVp is recommended, when only one voltage value is used. Ninety-five KVp was determined by the maximum limit of tube voltage in the appratus used. In order to estimate the effect of voltages on x-ray energy, exposure dose at 55, 80 and 95KVp were measured using a water phantom (18cm) and absorption coefficient of water(μ) was calculated at different tube voltage. The μ value decreased with increasing tube voltage. The μ value was so effected

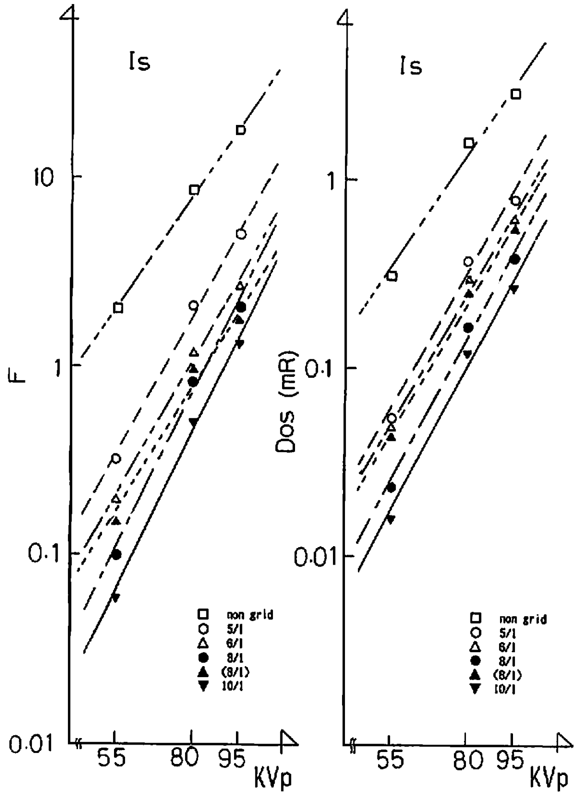

Fig. 4 Values of Is

Table 4. Values of Σ, K and B at 0.2sec of exposure time.; Σ=Tp/Ts, K=Tp/Tt, B=It"/It'=1/Tt.

Grid ratio	Trns Factor	55 KVp		80 KVp		95 KVp	
		F	Dos	F	Dos	F	Dos
5/1	Σ	3.40	3.59	1.84	2.83	2.52	2.57
	K	1.42	2.18	0.81	1.84	1.06	2.40
	B	2.78	3.57	1.75	2.70	1.56	3.33
6/1	Σ	4.89	3.00	4.07	2.71	3.87	2.41
	K	1.83	3.46	1.58	2.89	1.49	3.53
	B	4.17	7.69	2.78	5.56	2.56	6.66
8/1	Σ	4.80	5.43	4.22	4.00	3.89	3.62
	K	1.33	2.92	1.31	2.59	1.09	3.36
	B	5.56	7.69	3.45	5.88	3.13	7.14
(8/1)	Σ	7.71	3.86	6.20	3.50	5.18	3.11
	K	2.25	2.70	1.82	2.33	1.58	3.11
	B	4.17	5.00	2.94	4.17	2.78	5.56
10/1	Σ	8.33	6.20	7.00	4.75	6.14	4.56
	K	2.50	3.44	2.33	2.71	2.05	3.42
	B	10.0	11.1	5.56	7.14	4.76	8.33

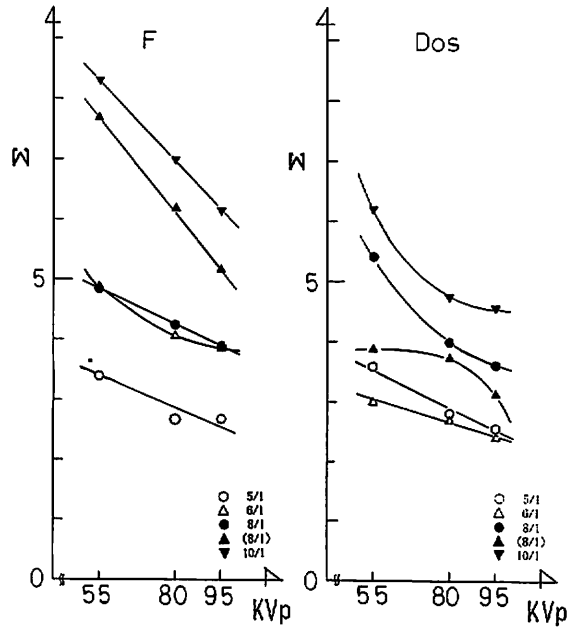

Fig. 5 Values of Σ

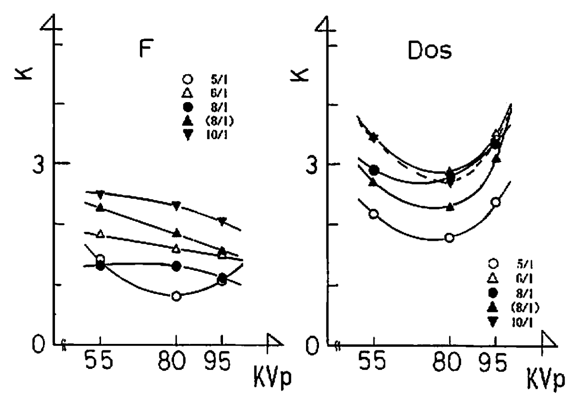

Fig. 6 Values of K

by tube voltage that the performances of grids should be extimated in considering voltage. Since the μ values by Dos were higher than those by F, measurements by F may under estimated the μ values. One of the reasons may be explained as fellow. In case of F, exposure is measured indirectly through screen-fluorescence system, while exposure is measured directly by dose meters. The effects of screen-flourorence system may be included in this result.

In order to estimated the performance of grids, measurements were usually performed using a fluorescent meter. In this study, measurements using dose meters were added and comparisons between Ip, It, and Is values by F and Dos were made. Furthermore, Σ values by F and Dos with increasing voltage were in cosiderable agreement. Σ and B values by F and Dos with increasing grid ratios were also in considerable agreement. However contrary to our expectation, K values by F and Dos

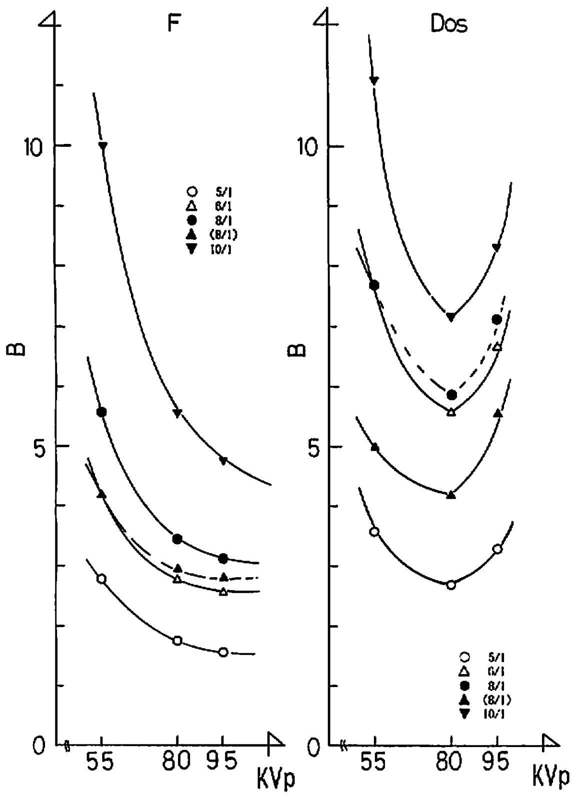

Fig. 7 Values of B

Table 5. Comparision of dose rate at each grid to non grid: Rp, Rt, and Rs(%) show the absorption ratio.

abs rat (%)	volt (KVp)	grid ratio 5/1	6/1	8/1	(8/1)	10/1
Rp	55	39.0	55.0	62.0	46.0	69.0
	80	32.0	48.0	56.0	44.0	62.0
	95	28.0	47.0	53.0	44.0	59.0
Rt	55	72.0	87.0	87.0	80.0	91.0
	80	63.0	82.0	83.0	76.0	86.0
	95	70.0	85.0	86.0	72.0	88.0
Rs	55	83.0	85.0	93.0	86.0	95.0
	80	76.0	81.0	89.0	84.0	92.0
	95	72.0	78.0	87.0	82.0	91.0

were not so in agreement. This discrepancy between F and Dos can not be explained in detail. One of the reasons may be that two kinds of dose meters were used at more and less than 2mR. These dose meters don't have the common region in measuring dose. The other reason may be that measurements by a dose meter are more sensitive at low voltages, with a small amount of fluorescence because of the low sensitivity of the screen against X-ray at low voltage.

In estimating the performance of grids by both F and Dos, Σ values seem to be the best. In estimating by F alone, Σ and K values were useful. B values seem to be improper because they don't represent the reduction effect. In our results, Σ, K, and B values changed prominently according to voltage. Therefore, the reduction effect by a grid was suggested to depend markedly on the voltage. Though the occurrence of scattered radiation and its reduction effect by a grid seem to be effected by tube current, exposure time, and phantom thickness, these factors were not compared in this paper.

In comparision of various grids, a grid with high density and high grid ratio had large reduction effect. Though a bucky grid is usually movable in the employment, it was examined at fixed condition in this study. A bucky grid, if movale, may have different Σ, K, and B vallues. The reduction effect by a cross grid was so higher than other kinds that a cross grid seems to be superior.

In addition to transmission of radiation, absorption ratios of radiation by grids were calculated. It decreased with increasing tube voltage. Absorption ratios of grids are also useful in estimating the reduction effect of grids.

CONCLUSION

The conclusions obtained in this study are as fellows.

1. The radiation at high voltage has a small μ.
2. Measurements by D may be more exact at low voltages, comparing with measurements by F.
3. The reduction effect of a grid decreases with increasing voltages.
4. A grid with high density and high grid ratio has large reduction effect.
5. The Σ and K values are more useful than B value in estimating the performance of a grid.
6. Absorption ratios of grids are also useful in estimating the performance of grids.

The performance of a grid is determined by the combined effect of various physical factors. Various grids have so different characteristics that an appropriate grid should be selected according to the exposure condition.

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