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The Performance of Phototimer in Remote Controlled X-ray Televison System.

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ABSTRACT

The performance of phototimer was examined using water phantom. The depth of water was changed from 5 to 20cm with 5cm interval in a polyacrylate container. Tube voltage was changed 50 to 120KVp with 10KVp interval, while tube current was constantly kept to be 100mA. Low phototimer sensitivity was selected. The phototimer density was changed from (−3) to 0 to 3 to 5. The results using BM-III and BF-III screen were compared. The following conclusions were derived.

1) With every phantom, constant film density (FD) was obtained at 90 to 110KVp of voltage. Within this range, phototimer was very useful.
2) In thick phantom, constant FD was obtained at higher voltage, while lower FD at lower voltage.
3) In thin phantom, constant FD was obtained at higher voltage, while higher FD at lower voltage.
4) At 50 to 80KVp, FD varied remarkably with phantom thickness and constant FD was not obtained. Therefore, phototimer couldn't accomplish the role satisfactorily at such lower voltage in the apparatus examined in this study.

If phototimer is correctly used under the proper condition, it is possible to obtain high quality images with least radiation.

INTRODUCTION

Frequent ocurrence of gastrointestinal disease in our country has markedly promoted the development of remote controlled X-ray diagnostic television system. The use of this system equipped with a phototimer made it possible to obtain the high quality images for gastrointestinal radiographies. The role of a phototimer is to control automatically the ocurrence of X-ray according to various factors such as tube voltage, current, field size, patient positioning, body thickness and so on. However, it is only under a limited condition that a phototimer plays the role although the performance of a phototimer has been improved through the eager efforts of clinical

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physicians and technologists. The performence of a phototimer on remote contralled X-ray television system has not been described previously.

The purpose of this paper is to evaluate the perfomance of phototimer at various condition.

MATERIALS and METHODS

I X-ray apparatus

The apparatus (type USM-11, Shimazu corp.) is consisted of the following units; (1) X-ray generator system, (2) image-receptor system and (3) remote controlled table system.

(1) X-ray generator system (model HD 150B)

The X-ray tube can be powered by three-phase high voltage generator[1]. In this tube of "CIRCLEX 0.5/1.5 U10CN-25" equipped with the rotating anode can be used both focus of 0.5 and 1.5mm. The heat-storage capacity is 80KHU. The exposure condition used in this generator should be limited under 80KHU. Therefore, in case of 100mA of current, the maximum exposure time is determined to be 3, 2 and 1sec at less than 80, 90 to 110 and more than 120KVp of voltage, respectively. The X-ray tube is placed in conventional mounts with collimator assemblies. Field size can be automatically adjusted by multiple lead vanes in a collimator of type RF-30. Additional filter of Aluminum (1.5mm) is equipped on the collimator.

(2) Image-receptor system

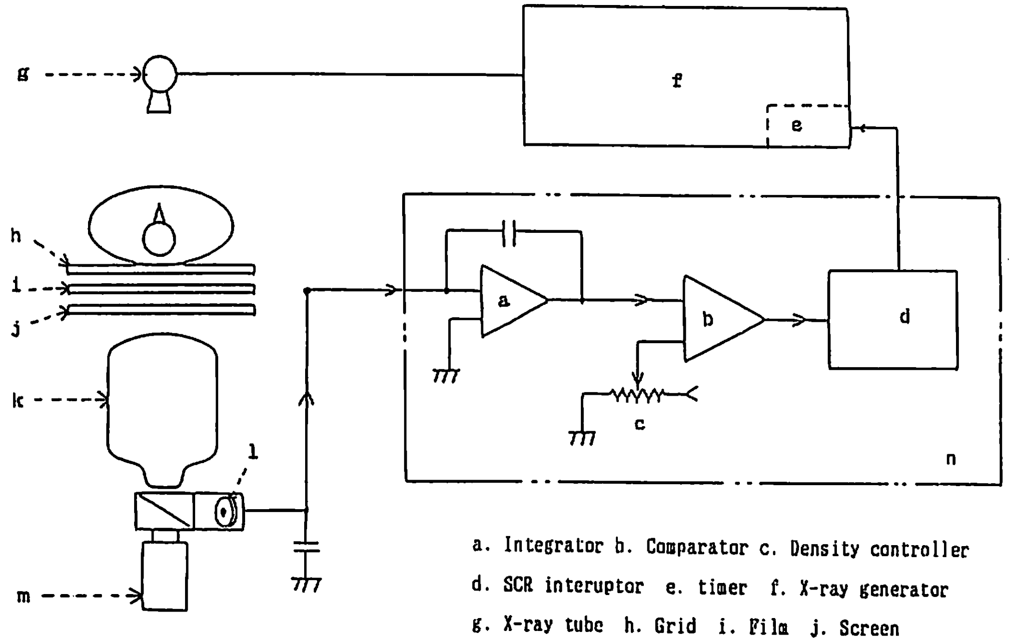
In image-recptor system includes (A) fluoroscopic system such as image intensifier (I. I.), lens, phototimer, television camera and monitor and (B) screen film system such as screen, film and film changer.

(3) Remote controlled table system

This device[2] belongs to over-tube type, where X-ray tube is equipped over the table and image receptor system under the table. Patient positioning can be adjusted by moving a table with remote control. A patient is required only his body's rolling on the table. The distance between focus and table was kepted to be 100cm.

2 Mechanism of a phototimer

Fig. 1 shows schematic illustration of a phototimer (model SPT-C10, Shimazu corp.). When screen (j) is exposed by X-ray, it emits fluorescence in proportion to amount of X-ray. On the other hand, the X-rays can be transformed into fluorescence by I. I (k) after they passed through the screen and then changed the electric current by photomultiplier (l). The voltage, which is caused by current from a photomultiplier, is compared with the standard voltage in the comparator (b). The standard voltage is altered by changing variable resistance in the a phototimer density controller (c) to obtain the desired film density. When the integrated current attains certain threshold value in a integrator (a) using a condenser, the signal to inhibit X-ray exposure is generated in a SCR (silicon controlled rectifier) interruptor (d). The dead



a. Integrator b. Comparator c. Density controller
d. SCR interuptor e. timer f. X-ray generator
g. X-ray tube h. Grid i. Film j. Screen
k. Image Intesifier l. Photomultiplier m. Camera
n. Phototimer control area

Fig. 1 Schematic mechanism of phototimer

time in this circuit was 20ms.

3 Measurements

(1) Phantom

The depth of water was changed 5 to 20cm with 5cm interval in a polyacrylate container.

(2) Exposure conditions

a) Tube voltage

Tube voltage was changed 50 to 120kvp with 10kvp interval.

b) Tube current

Tube current was constantly kept to be 100mA.

c) Field size

X-ray beam was automatically limited so that exposure field was 10.0*12.5cm on the film.

(3) Phototimer sensitivity

The Phototimer sensitivity in this device can be selected out of three kinds of low, medium and high, according to the kind of screen, When the sensitivity of FS-screen is 100, that of MS- or HS-screen is 160 or 240, respectively. Low sensitivity was selected in this study because a great deal of fluorescence is emited.

(4) Phototimer density

Appropriate phototimer density shoud be selected to obtain the desired film density.

By changing variable resistance in the circuit, phototimer density can be varied from (−5) to 5, totally eleven steps. The change of one step corresponds to that of 15% of the standard voltage and that of 0.1 in film density. When the standard phototimer density which is represented as "Zero" is selected, the standard film density can be obtained. Positive or negative phototimer density corresponds to higher or lower film density than the standard, respectively. Four steps of (−3), 0, 3 and 5 were selected in this study.

(5) Screen-film system

Using both BM-III and BF-III screen (Kyokko corp.), the film density was compared. Film (Konica corp.) belonged to "A" type in 20*25cm. It was used dividing into 4 parts. All films were processed in X-ray film automatically processor (model QX 130, Sakura corp.) using XD-90 developer (Konica corp.) at 31℃ and XF fixer (Konica corp.).

(6) Measurements of film density

Film density was measured using a densitometer (model PDA-65, Sakura corp.).

RESULTS

(1) Effects of tube voltage and phantom thickness on film density.

Using BM-III screen, effects tube voltage (Fig. 2a) and phantom thickness (FIg. 3) on film density (FD) were evaluated at standard phototimer density.

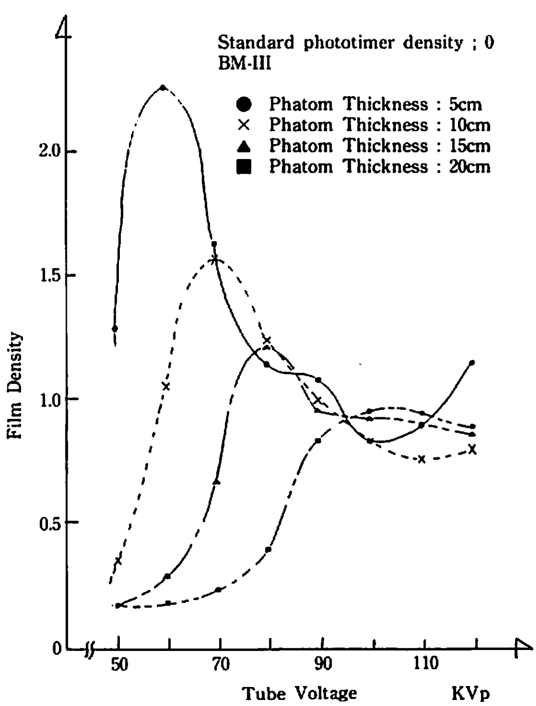


Fig. 2a Film density versus tube voltage in case of BM-III screen

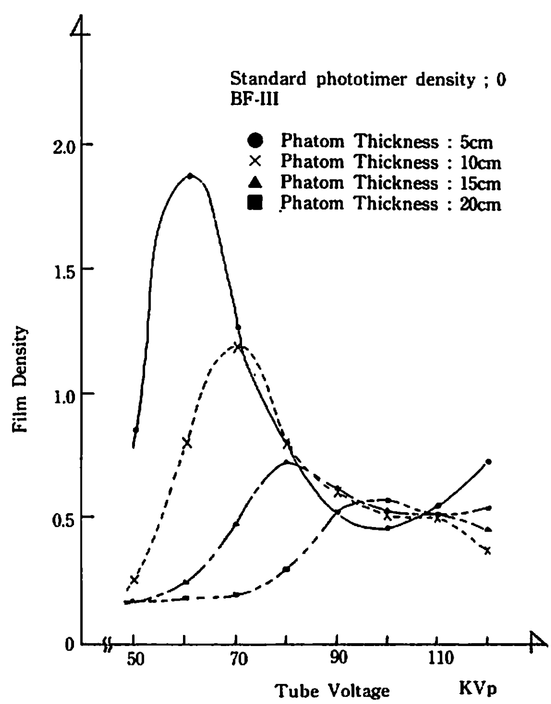


Fig. 2b Film density versus tube voltage in case of BF-III screen

a) 5cm-phantom

Constant FD of 0.85 was obtained at 100 and 110KVp, while higher FD at 50 to 90 and 120KVp. The maximum FD of 2.3 was obtained at 60KVp and 2.5 times higher than constant FD. Lower FD was not obtained.

b) 10cm-phantom

Constant FD of 0.8 was obtained at 100 to 120KVp, while higher FD at 60 to 90KVp. The maximum FD of 1.6 was obtained at 70KVp and twice higher than constant FD. Lower FD of 0.4 was obtained at 50KVp and 0.5 times lower than constant FD.

c) 15cm-phantom

Constant FD of 0.9 was obtained at 90 to 120KVp, while higher FD at 80KVp alone. The maximum FD of 1.2 was 1.3 times higher than constant FD. Lower FD was obtained at 50 to 70KVp. The minimum FD of 0.2 was obtained at 50kVp and 0.22 times lower than constant FD.

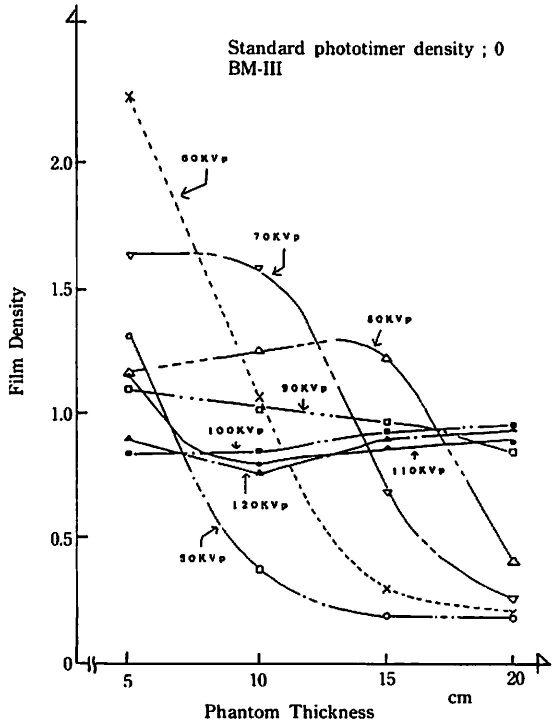


Fig. 3 Film density versus phantom thickness in case of BM-III screen

d) 20cm-phantom

Constant FD of 0.95 was obtained at 100 to 120KVp and represented the maximum value. Lower FD was obtained at 50 to 90KVp. The minimum FD of 0.2 was obtained at 50 and 60 KVp and 0.2 times lower than constant FD.

Consequently, constant FD of 0.8 to 0.95 were obtained at 100 and 110KVp in every phantom. Furthermore, the FD at 90KVp was similar to constant FD. In 20cm-phantom, constant FD was obtained at higher voltage, while lower FD at lower voltage. On the other hand, in thin phantom constant FD was obtained at higher voltage, while higher FD at lower voltage. The voltage showing the maximum FD shifted to higher voltage with increasing phantom thickness.

(2) Effects of phototimer density on FD.

Using BM-III screen, effects of phototimer density (PD) on FD were evaluated (Fig.4). PD values were changed in discrete steps from (−3) to 0 to 3 to 5.

a) 5cm-phantom (Fig. 4a)

The maximum FD was obtained at 60KVp for every PD value. At lower than 60KVp, significant difference in FD was not observed among different PD values. At higher than 70KVp, FD increased with increasing PD value. For the same PD value, FD decreased steadily with increasing voltage at 70 to 100 or 110KVp. The minimum FD was obtained at 100KVp for (−3), 0 and 5 of PD and at 90KVp for 3 of PD. At higher than 100 or 110KVp, FD increase for every PD value. Constant FD could not be

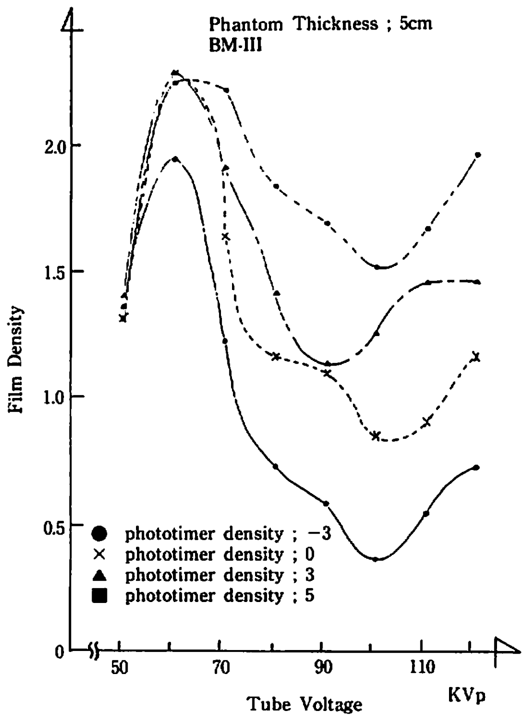


Fig. 4a Film density versus tube voltage in 5cm-phantom

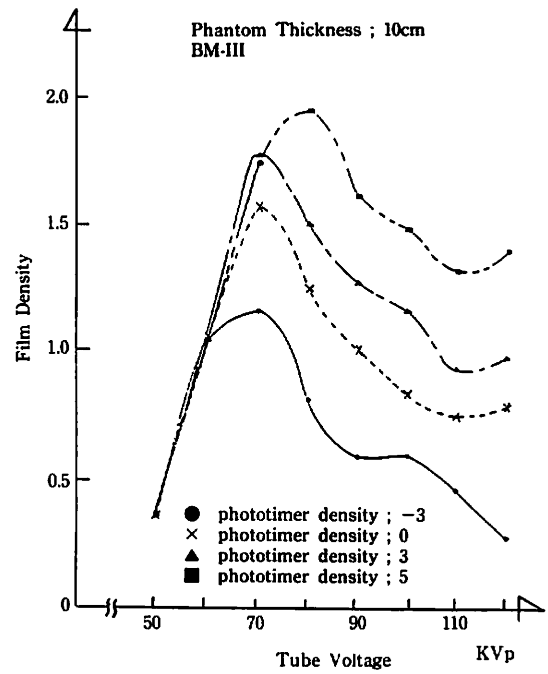


Fig. 4b Film density versus tube voltage in 10cm-phantom

obtained.

b) 10cm-phantom (Fig. 4b)

The maximum FD was obtained at 70KVp for (−3), 0 and 3 of PD and at 80KVp for 5 of PD. At lower than 60KVp, significant difference in FD was not observed among different PD values. At higher than 80KVp, FD increased steadily with increasing PD value. For the same PD value, FD decreased steadily with increasing voltage. Constant FD of 0.9 for 0 of PD was obtained at 100 to 120KVp, while that of 1.0 for 3 of PD at 110 and 120KVp. The FD for (−3) of PD decreased steadily with increasing voltage. The minimum FD for 5 of PD was obtained at 110KVp.

c) 15cm-phantom (Fig. 4c)

The maximum FD was obtained at 80KVp for (−3) and 0 of PD, at 90KVp for 3 of PD and at 100KVp for 5 of PD. The voltage showing the maximum FD shifted to higher voltage with increasing PD value. At lower than 70KVp, significant difference in FD was not observed among different PD values. At higher than 90KVp, FD increased with increasing PD value. Constant FD of 0.55 and 0.9 at 90 to 120KVp were obtained for (−3) and 0 of PD, respectively. FD for 3 and 5 of PD decreased steadily with increasing voltage.

d) 20cm-phantom(Fig. 4d)

The maximum FD was obtained at 90KVp for (−3) of PD, at 100KVp for 0 of PD and at 110KVp for 3 and 5 of PD. The voltage showing the maximum FD shifted

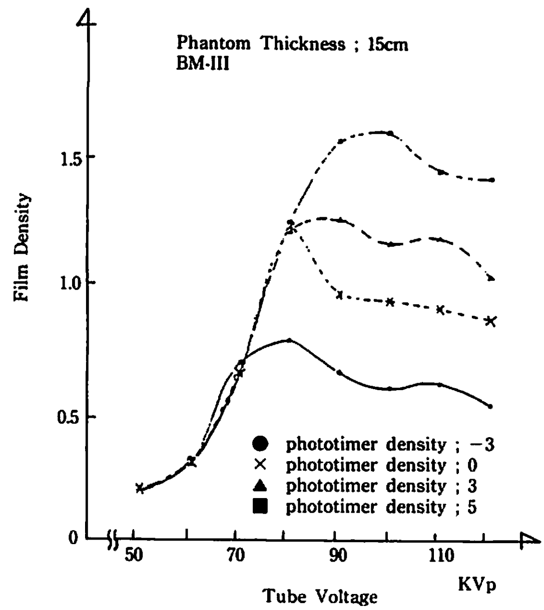


Fig. 4c Film density versus tube voltage in 15cm-phantom

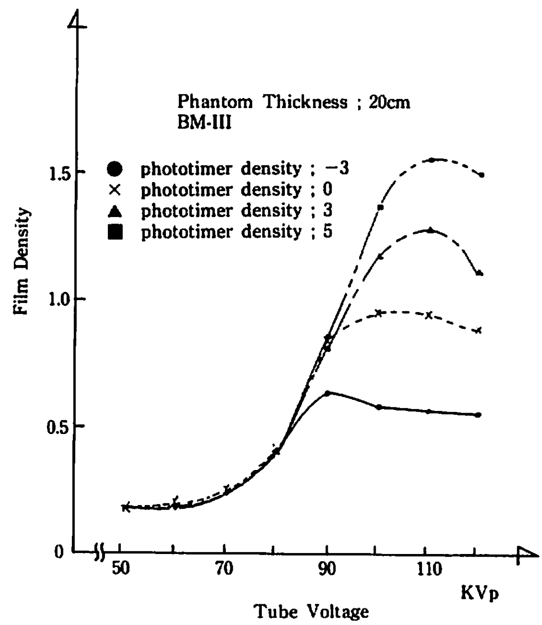


Fig. 4d Film density versus tube voltage in 20cm-phantom

to higher voltage with increasing PD value. At lower than 80KVp, significant difference in FD was not observed among different PD values. At higher than 90KVp, FD increased with increasing PD value. Constant FD for (−3) and 0 of PD were obtained at 100 to 120KVp and were 0.6 and 0.9, respectively. Constant FD was not obtained for 3 and 5 of PD.

Consequently, in case of 5cm-phantom, constant FD was not obtained. In case of 10cm-phantom, constant FD was obtained for 0 and 3 of PD. In cases of both 15cm- and 20cm-phantoms, constant FD were obtained for (−3) and 0 of PD. Therefore, phototomer seems not to be useful in 5cm-phantom.

(3) Comparision between BM-III and BF-III screen

The results using BF-III screen were compared with those using BM-III screen (Fig. 2b). Constant FD in BM-III and BF-III were 0.8 to 0.95 and 0.5 to 0.6, respectively and the former was approximately 1.8 times higher than the latter. FD between both screens showed the proportional relation at the same exposure condition.

DISCUSSION

The role of phototimer is to control exposure time automatically according to amount of x-ray to obtain high quality images. Since amount of X-ray is effected by tube voltage, current, field size, patient positioning, body thickness and so on, these factors should be considered in evaluating the performance of phototimer. Furthermore, it is important to consider the sensitivity of screen, and I.I., dead time in SCR circuit and the maximum nominal output power (MNOP) in the generator.

Firstly, the size of the object should be considered. If the object is too small or too imhomogeneous, phototimer can't be used effectively[3].

Secondly, dead time in SCR circuit should be shorter. In our results higher FD was obtained at 120KVp, while constant FD at 90 to 110KVp. This reason appears to depend on the delayed signal in SCR circuit due to dead time of 20ms. When voltage and current are very high and exposure time is very short, X-ray is overexposed due to dead time.

Thirdly, MNOP should be greater. Beside the control due to phototimer, generator receives the constraint by MNOP because the use over the range of MNOP leads to the destruction of the generator. Since MNOP is represented by the product of voltage, current and exposure time, the maximum exposure time is decided by voltage at constant current. As shown in Fig. 2a, in 15cm- and 20cm- phantoms lower FD was obtained at 60KVp. For this reason, it was supposed that X-ray was inhibited to generate after the exposure for 3sec by the constraint of MNOP before the phototimer completes its function.

Fourthly, the sensitivity of screen should be also considered. In the comparison between BM-III and BF-III, constant FD of 0.8 to 0.95 and that of 0.5 to 0.6 were obtained. BM-and BF-screen are well known to correspond to MS-and FS-screen, respectively. Therefore, the sensitivity ratio of 0.9/0.55 for BM/BF in our results showed good agreement with that of 160/100 for MS/FS.

Finally, the performance of phototimer itself should be considered. In our results, in 5cm-phantom higher FD was obtained at 60KVp. This reason is imagined to be why the amount of X-ray was not fully perceived by the phototimer on account of low energy X-ray. As a result X-ray was overexposed. Higher FD was obtained also at 70 and 80KVp. Similarly, this reason is imagined to be due to insufficient operation of the phototimer on account of low energy X-ray.

Contrary to our prediction that constant FD would be obtained at lower voltage in thin phantom, higher FD was obtained at 60KVp in 5cm-phantom. Our apparatus examined in this study has been used for the educatinal training in our department for past twelve years. In recent apparatus equipped with excellent SCR circuit, such a discrepancy may not be observed.

The following conclusions were derived in this study.

1) In every phantom, constant FD was obtained at 90 to 110KVp. Within this range, phototimer is more useful.
2) In thick phantom, constant FD was obtained at higher voltage, while lower FD at lower voltage. Therefore, when patient body is such thick as adult with obesity, radiography taken at lower voltage is suggested to show lower FD.
3) In thin phantom, constant FD was obtained at higher voltage, while higher FD at lower voltage. Therefore, when patient body is such thin as children or old man with emaciation, radiography taken at lower voltage is suggested to show higher

FD.

4) FD varied remarkably with phantom thickness at 50 to 80KVp and constant FD was not obtained. Therefore, the phototimer can't accomplish the role at such lower voltage in the apparatus employed in this study becouse the detecting area of this phototimer locates at the back of the screen and x-ray is absorbed by lead plate in the cassette.

In conclusion, if phototimer is correctly used under the proper condition, it is possible to obtain high quality images with least radiation.

REFERENCES

1. Kitamura. M, Sakamoto. G, Uno. Y, Kurimoto. I : Three-Phase X-Ray High Voltage Generator, Model HD 15 0B-30. Shimazu Review. Vol. 42. No.1. 149-153, 1985 (in Japanese)
2. Imai. T : Human engineering for a remote-controlled diagnostic x-ray system. Jpn. J. Radiol. Technol. Vol. 37, 795-799, 1981
3. Takeyoshi. S : Basic research for chest rediography. Jpn. J. Radiol. Technol. Vol. 31, 271-276, 1975

遠隔操作式Ｘ線透視撮影機におけるホトタイマーの性能について

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要　　　旨

ホトタイマーは一定の写真濃度を得るために，被写体や体位に左右されずに自動的にＸ線の発生を制御するものである。しかし実際にはＸ線検出方式の違いや信号に対する応答時間の遅れ等、装置の機構や種々の条件により写真濃度が異なってくる。ホトタイマーの性能を評価するために水ファントムを用いて検査した。ファントムの厚さはアクリル容器内で５～20 cm まで５ cm 段階で変化させた。管電流は100 mA 一定とし，管電圧は50～120 KVp まで10 KVp 単位で変化させた。ホトタイマーの感度は低スクリーン用を選択し，またホトタイマーの濃度は（－３），０，３，５まで変化させた。撮影のための増感紙は BM-III と BF-III を用い比較した。

結論　１）管電圧90～110 KVp ではすべてのファントム厚で一定濃度が得られた。この管電圧領域ではホトタイマーは大変使いやすい。

２）厚いファントムでは一定濃度は高い管電圧で得られた。低い管電圧では低い濃度となった。

３）薄いファントムでは一定濃度は高い電圧で得られた。低い電圧では高い濃度となった。

４）50～80 KVp まではすべてのファントムで一定濃度は得られなかった。それ故この研究で用いた装置では低電圧では十分な性能を発揮することができないことが明らかになった。