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X-RAY TELEVISION INSTALLATION PROVIDED WITH A FULL SIZE ROLL FILM CHANGER FOR MASS SURVEY OF GASTRODUODENAL DISEASES*

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SINCE about 10 years ago, many physicians and radiologists in Japan have made efforts to establish a method to examine as many subjects as possible, by using various devices for detection of gastroduodenal diseases because of the exceptionally high incidence of gastric cancer and allied diseases in this country. The methods applied under the circumstances, in which limited number of radiologists have to examine a large number of cases, by using the limited number of facilities, are divided into 4 groups: (1) fluororadiography by using 60 mm. lens camera without fluoroscopy; (2) fluororadiography by using 70 mm. or 100 mm. mirror camera without fluoroscopy; (3) 70 mm. filming of 9 inch or 11 inch image intensifier output screen under television fluoroscopy; and (4) direct full size roentgenography under television fluoroscopy. The latter method is the subject which the authors have studied for the last 10 years.[2–5,7] Recently we have succeeded in constructing a new x-ray television installation, whose main function is direct roentgenography by using a roll film of 30.4 cm. in width under television fluoroscopy by remote control.

In the present communication we report the construction, performance evaluation, and patient dose concerning the newly constructed x-ray television installation with a full size roll film changer, in comparison with those of fluororadiographic techniques by using lens or mirror cameras, and those of filming of an image intensifier output screen.

CONSTRUCTION OF THE X-RAY TELEVISION INSTALLATION WITH A FULL SIZE ROLL FILM CHANGER

The general view of the present x-ray television installation is shown in Figures 1 and 2. The special feature of this device is that it is provided with a newly developed roll film changer which is capable of containing a roll film, 30.4 cm. wide and up to 25 m. in length (Fig. 3). The changer has the following functions:

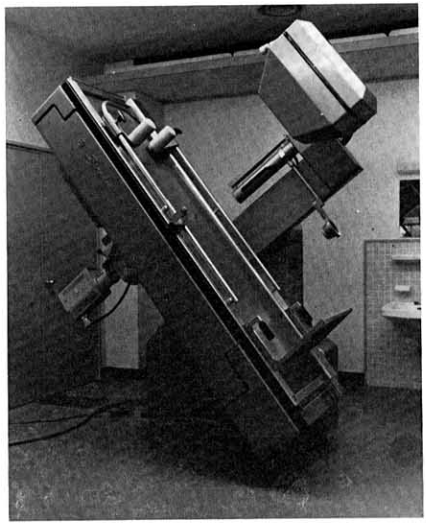

FIG. 1. General view of the newly constructed radiographic-fluoroscopic table with a plumbicon camera for mass survey of gastroduodenal diseases.

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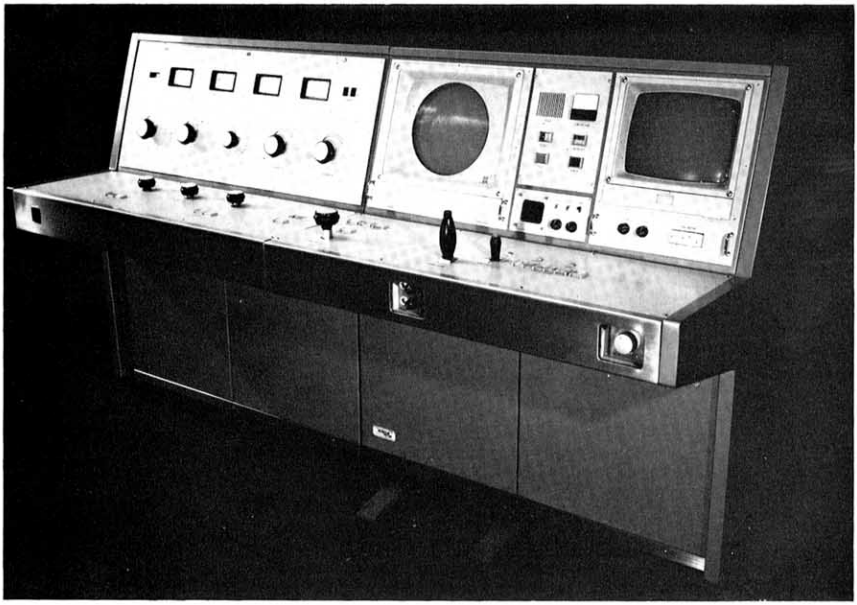

FIG. 2. The control desk of the x-ray television installation for mass survey of gastroduodenal diseases.

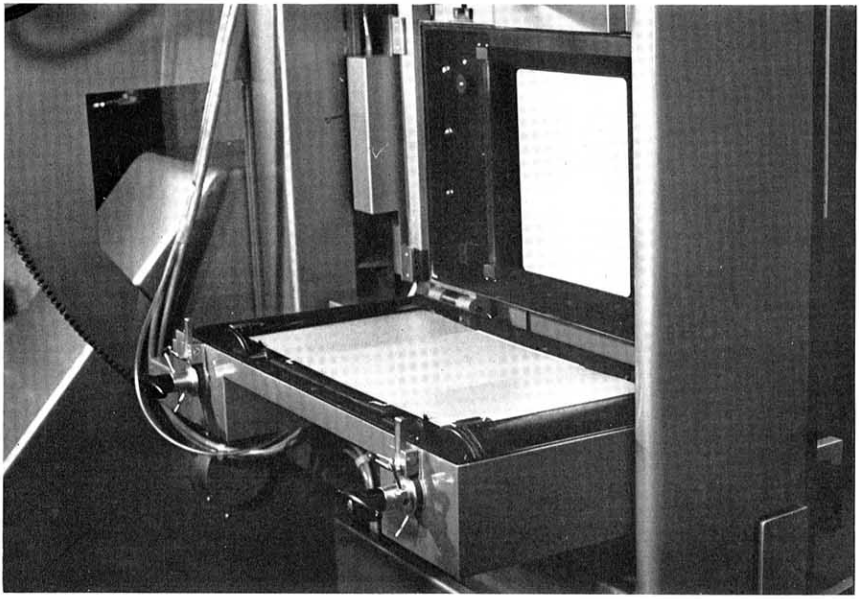

FIG. 3. The full size roll film changer installed immediately behind the table-top of the radiographic-fluoroscopic table. The changer is open to show the inside.

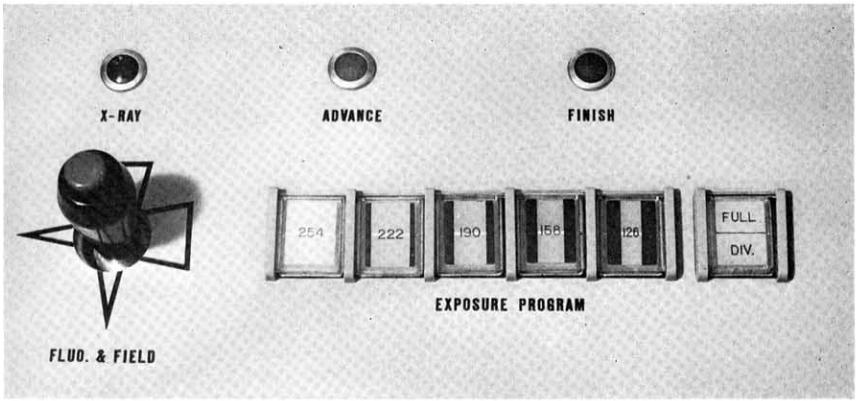

FIG. 4. The push buttons for selection of a film area to be exposed are seen in the center of the control panel arranged in a line.

1. The size of a film being used can be changed in accordance with the size of the stomach, which shows considerable variation individually and varies remarkably with the posture of the patient on a tilting table during x-ray examination. In the present device the available alterations of film size are 5 kinds in length, *i.e.*, 12.6, 15.8, 19.0, 22.2, and 25.4 cm.; and 2 kinds in width, *i.e.* 15.2 and 30.4 cm. Hence, the total combination of different areas of the film utilized in this device is 5×2. Regulation of the film area to be exposed is controlled by co-ordination of the following 3 mechanisms: rolling up the roll film in the appointed length; masking by lead plates over the film; and limiting the x-ray beam by multi-leaf shutter in the x-ray tube housing. Since these mechanisms are automatically controlled, all that a radiologist has to do for selection of a film area is to push a selection button on the control panel after estimating the size of a stomach by television fluoroscopy (Fig. 4). The data, on which the above mentioned film areas provided in this device are based, will be described in the following chapter.

2. Pressing of the intensifying screens against a film is done by blowing air just before roentgenography from an air compressor into a rubber bag on which the intensifying screen is placed (Fig. 3). Immediately after roentgenography the air is evacuated from the bag for the coming movement of the roll film.

3. The roll film changer, which is installed directly behind the radiographic-fluoroscopic table-top, is out of the x-ray beam, while telefluoroscopy is carried out, and it moves rapidly into the x-ray beam immediately before roentgenography (Fig. 5). Consequently cassettes have become unnecessary in the present installation.

One of the important alterations in this device is utilization of plumbicon tube in place of vidicon tube which has been utilized in our previous x-ray television installations. Employment of a 9 inch image intensifier is provided, as before, because a visual field of this size is necessary and sufficient for x-ray examination of the stomach and duodenum.[3–5]

In order to shorten the duration of the x-ray examination, an increase in speed of such movements of the radiographic-fluoroscopic table as longitudinal sliding, lateral traverse, and up and down tilting were realized in the present device. The data are presented in Table 1 in comparison with our previous tilting table which was

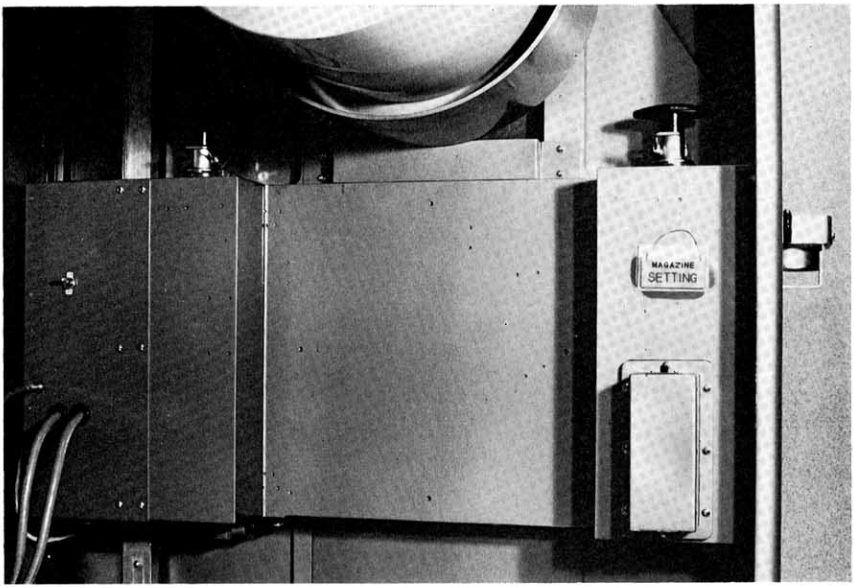

Fig. 5. The full size roll film changer which is set out of x-ray beam range. A part of the image intensifier is visible above the changer.

constructed in 1961 as the first one of the remotely controlled radiographic-fluoroscopic tables in Japan.[4]

Estimation of Useful Film Size in X-Ray Examination of the Stomach and Duodenum

Generally speaking the size of the film which we use in x-ray examination is not necessarily decided by the size of an object itself, but the size of a film offered by the film companies. On the contrary, the areas of film to be exposed in the present device are selected according to the size of the stomach and duodenum.

The following experiments were carried out to estimate the size of a stomach and duodenum which were roentgenographed on the full size x-ray films: x-ray examination of the stomach and duodenum was performed in more than 1,000 Japanese adults, by using the remotely controlled x-ray television unit which we reported in our previous paper. Focus-film distance in roentgenography was 100 cm. and the size of the focus was 1 mm. The size of a stom-

Table I

Speed of Various Kinds of Movements in the Remotely Controlled Radiographic-Fluoroscopic Tables

Type of Movements	The Previous Device	The Present Device
Longitudinal Sliding	3.5 cm./sec.	5.0 cm./sec.
Lateral Traverse	3.0 cm./sec.	3.5 cm./sec.
Up and Down Tilting	90°/20 sec., 90°/40 sec.	90°/15 sec., 90°/30 sec.

Table II

MEAN VALUES OF THE SIZE OF A STOMACH INCLUDING DUODENAL CAP ROENTGENOGRAPHED ON A FULL SIZE X-RAY FILM*

Position of Patient	Sex	Size of Sample	Longitudinal Side Mean Value±S.D. in cm.	Size of Sample	Transverse Side Mean Value±S.D. in cm.
Prone	Male	671	14.1±3.1	663	14.8±2.2
	Female	452	15.8±3.5	457	14.4±2.3
Supine	Male	681	13.8±2.9	677	15.5±1.9
	Female	459	14.8±2.5	463	14.9±1.9
Erect, A–P	Male	668	23.8±3.6	668	16.0±1.9
	Female	480	26.1±3.3	450	14.7±1.9
Erect, RAO	Male	658	24.7±3.6	649	13.0±1.9
	Female	472	26.8±3.2	436	11.9±1.8

* Focus-Film Distanc: 100 cm.
A—P=Anteroposterior; RAO=Right Anterior Oblique.

ach including duodenal cap was measured on x-ray films exposed in various positions used in routine examination. Figure 6, *A–D*, shows the method of measurement giving an example. The results are summarized in Table II, demonstrating that the mean values of the transverse side of a stomach including the duodenal cap are about 3/5 of a short side of an ordinary 30.4×25.4 cm. film. Thus saving of film area used in x-ray examination of the stomach and duodenum is possible in the transverse direction, regardless of a patient's position, while that for longitudinal direction is possible only when a patient is supine or prone in position. More exact observation concerning this is shown in Figure 7, *A–D*, representing distributions of cases as regards the value of the transverse side of a stomach including the duodenal cap in erect position and in the recumbent position, and the value of the longitudinal side of these organs in erect position and in recumbent position, respectively. From these analyses, available film-widths and film-lengths in the roll film changer were decided (Fig. 8).

DEVELOPMENT AND STORAGE OF THE FULL SIZE ROLL FILM

Procurement of a roll film 30.4 cm. in width is not difficult, since an ordinary 30.4×25.4 cm. x-ray film is produced originally in the form of a 30.4 cm. roll film and is then cut off for making sheet film by the film companies.

Loading a roll film into the changer as well as removing the film from it is a very simple operation. Here, the authors wish to recollect the troublesome, time-consuming work of parking and changing sheet films in the course of x-ray examination of the stomach and duodenum when an ordinary radiographic-fluoroscopic table is used, which constitutes 25 per cent of total time of the examination for each case.[5]

Processing of the roentgenographed roll film is easily performed by using an automatic x-ray film processing unit of roller type. In our department, we have designed a guide which can be installed at the entrance of the automatic processing unit in order to make proceeding of a roll film exactly rectangular to the rollers of the unit (Fig. 9). This equipment as well as a specially designed roller to roll up a roll film, with which the outlet of the processing unit is fitted, makes a contribution to facilitate the processing of a roll film (Fig. 10). The time required to complete the processing of the roll film is 27 minutes per 20 m. After completion of the processing, the roll film

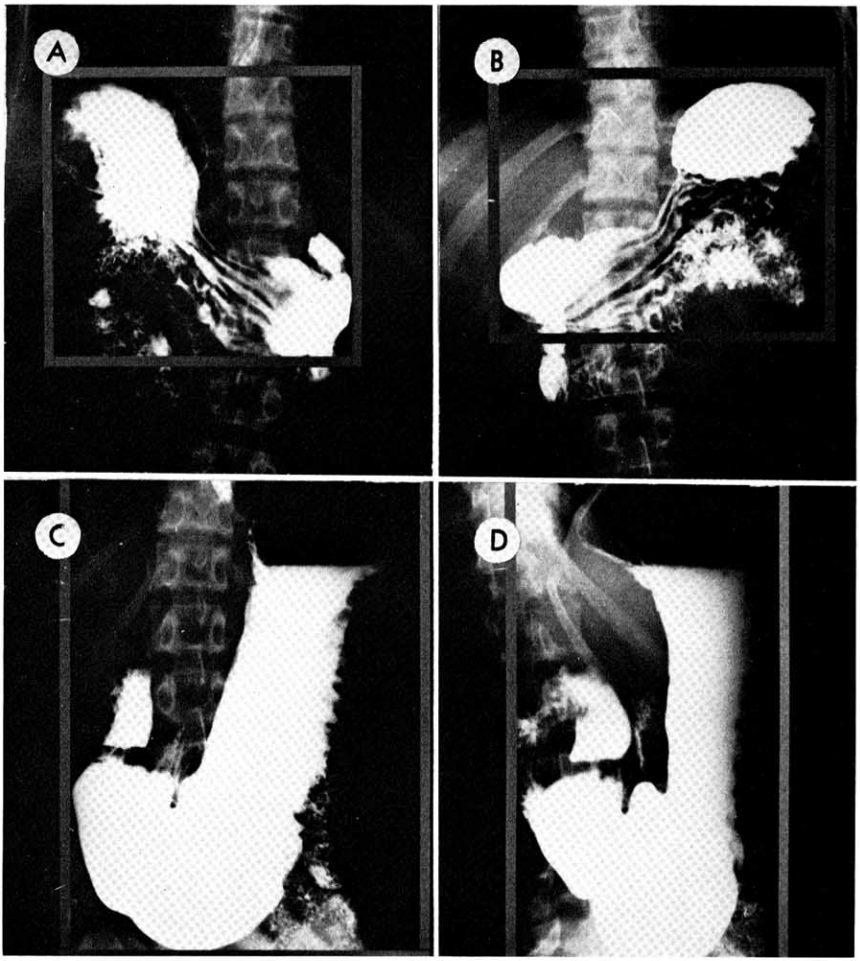

Fig. 6. (*A–D*) The method of measurement of the size of a stomach including duodenal cap roentgenographed on a full size x-ray film in various positions.

is cut off per case and put in a cover which is 31 cm. in width and 75 cm. in length. If the length of the film per case is over 75 cm., the film is cut off into 2 sheets. The length of the cover was decided from the following data: when 6 exposures per case—which is the average frequency of exposures in mass x-ray survey of the gastroduodenal diseases in the authors' department—are performed, the length of a roll film required is less than 75 cm. in 90 per cent of the cases examined (Fig. 11).

Performance Evaluation of Radiographic Systems

Performance evaluation of the following

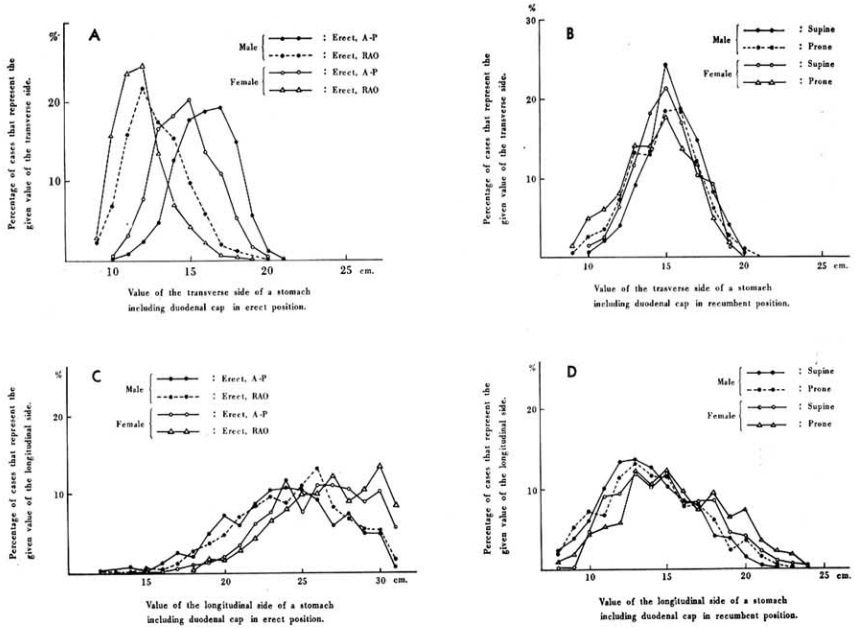

Fig. 7. (*A–D*) Value of the transverse and longitudinal sides of a stomach including duodenal cap measured on full size x-ray films in various positions.

Table III

TECHNICAL DATA OF THE RADIOGRAPHIC SYSTEMS UNDER PERFORMANCE EVALUATION BY USING THE FREQUENCY RESPONSE METHOD

Radiographic Systems	Generator	Focal Spot Size (mm.)	FSD (cm.)	Camera	Grid Ratio	Intensifying Screen	Film
Fluororadiography, using 60 mm. lens camera	Toshiba, KCD-12 sp., Condenser Discharge, 1.5 μF	2.0×2.0	90	Canon, Lens Camera F 1.5	4.5:1	Matsuda-DPD	Fuji 60 mm.
Fluororadiography, using 70 mm. mirror camera	Toshiba, KCD-12 sp., Condenser Discharge, 1.0 μF	2.0×2.0	90	Odelca-70-7-U, F 0.63	4.5:1	Kruppa-9D	Fuji 70 mm.
Fluororadiography, using 100 mm. mirror camera	Toshiba, KCD-12 sp., Condenser Discharge, 1.5 μF	2.0×2.0	90	Odelca-100-17-S F 0.65	4.5:1	Kruppa-9D	Gewalt Scopix G, I.S. 100 mm.
70 mm. filming of 11 inch image intensifier output screen	Shimazu, UD-150-L, Full Wave	0.5×0.5	100	Canon, CXIA-70, F 4.5	5:1	Shimazu, 11 inch I.I. Output Screen	Fuji 70 mm.
Direct roentgenography, using the full size roll film of the present x-ray television unit	Shimazu, UD-150-L, Full Wave	1.0×1.0	100	—	12:1	Kyokko, New MS	Fuji-KX

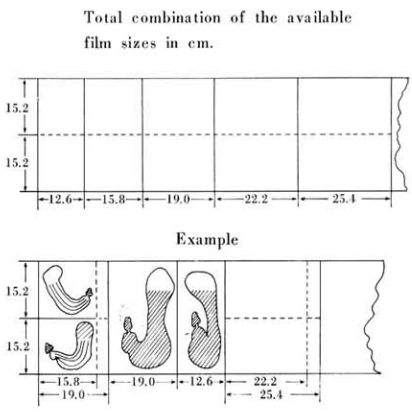

FIG. 8. Available film sizes in the roll film changer.

radiographic systems was carried out by using the frequency response method compared to: (1) fluororadiography, using 60 mm. lens camera; (2) fluororadiography using 70 mm. mirror camera; (3) fluororadiography, using 100 mm. mirror camera; (4) 70 mm. filming of 11 inch image intensifier output screen; and (5) direct roentgenography, using the present x-ray television unit with the full size roll film changer. The technical data of the systems under evaluation are summarized in Table III.

A square wave test pattern produced by Herr Funk, Optiker, West Germany,[6] was placed in the middle of plexiglass phantom plates 17 cm. thick in total and roentgenographed by the above mentioned various systems. The resulting images were scanned with a microdensitometer. The scans were then converted into the graphs indicating the change of contrast. Thus the obtained value of contrast was converted again into modulation transfer function, using Coltmann's equation:[1]

$$R(\omega) = \frac{\pi}{4}\left[S(\omega) + \tfrac{1}{3}S(3\omega) - \tfrac{1}{5}S(5\omega) + \tfrac{1}{7}S(7\omega) \cdots\right],$$

where $R(\omega)$ = *modulation transfer function to sine wave input;* $S(\omega)$ = *contrast to square wave x-ray; and* ω = *spacial frequency.*

The results are illustrated in Figure 12. As shown in this Figure, 70 mm. filming of 11 inch image intensifier output screen and the fluororadiography by 60 mm. lens

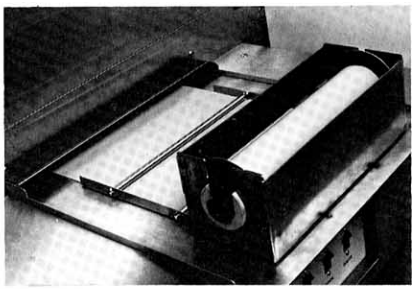

FIG. 9. A guide installed at the entrance of the automatic processing unit to make a roll film proceed exactly rectangular to the rollers of the unit.

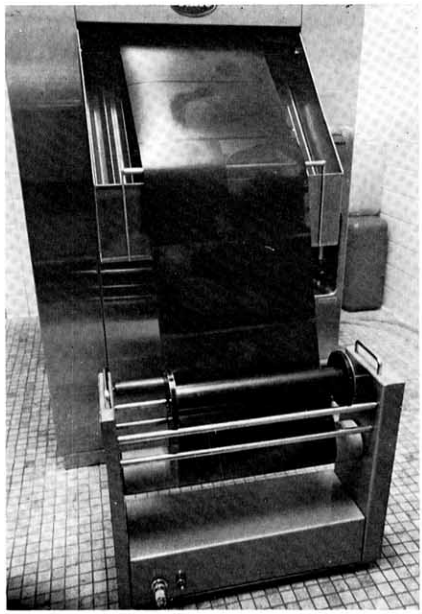

FIG. 10. A roller installed at the outlet of the processing unit to roll up a roll film.

camera are much inferior to the direct roentgenography, using the full size roll film of the x-ray television unit. The fluororadiography, using 100 mm. or 70 mm. mirror camera is between the 2 in performance evaluation by employing modulation transfer function.

PATIENT DOSE

In order to compare the patient doses during x-ray examination of the stomach and duodenum by the above mentioned 5 different kinds of methods, we employed the human phantom of a 19 cm. thick abdomen. The skin dose was measured on each device at the input position of the roentgen beam to the phantom, using the Philips universal dosemeter. The technical data for roentgenography presented in Table IV were used in these measurements presenting roentgenograms of presumably best quality of the human phantom for each technique.

While the patient skin dose is usually small in the filming of an image intensifier output screen, the skin dose in other fluororadiographic techniques is much greater than that in direct roentgenography by using the full size roll film changer: provided the skin dose in the direct roentgenography is 1, doses in the fluororadiography by using 100 mm. mirror camera, 70 mm. mirror camera and 60 mm. lens camera are about 2, 4 and 6, respectively, for each exposure.

On the other hand, the filming of an image intensifier output screen and the full size roentgenography by x-ray television unit are principally accompanied by television fluoroscopy. Hence, the patient dose due to television fluoroscopy has to come into consideration for these 2 techniques. The same method, as described in measurements of patient dose due to roentgenography, was applied for evaluation of patient dose due to fluoroscopy. The results represent remarkable reduction of patient dose in telefluoroscopy by the plumbicon television unit in comparison with that by a conventional fluoroscopic screen. For example, the skin dose to the patient 19 cm. thick at the abdomen is estimated 4,000 mr per minute from a conventional fluoroscopy, while 700 mr per minute is the skin dose from a television fluoroscopy by using plumbicon camera. Table V summarizes the estimated patient's skin doses during the above mentioned various x-ray techniques for mass survey of gastroduodenal diseases, on the assumption that 6 exposures are per-

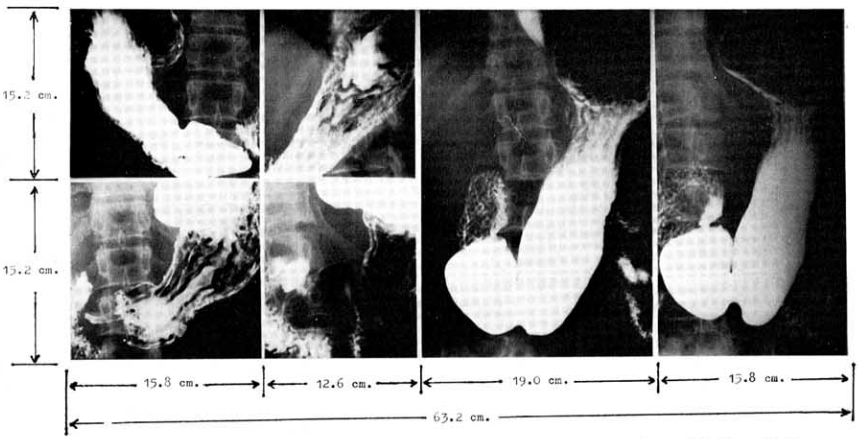

Fig. 11. Example of roentgenograms of a stomach and duodenum recorded by a full size roll film.

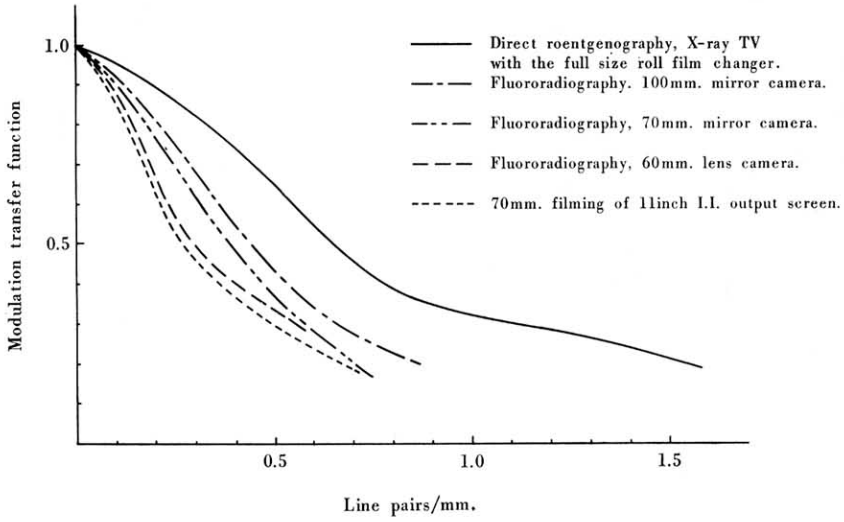

Fig. 12. Modulation transfer function of various radiographic systems when using a 17 cm. plexiglass phantom.

formed per case for each technique and the duration of fluoroscopy is 3 minutes per case for the filming of an image intensifier output screen under x-ray television fluoroscopy as well as for the direct roentgenography by using full size roll film under telefluoroscopy.

Discussion

The practical methods of mass x-ray survey for gastroduodenal diseases which have been applying in Japan are divided into 3 groups: (A) fluororadiography, without fluoroscopy in most of them; (B) filming of an image intensifier output screen

Table IV

Skin dose to the human phantom* per exposure in various radiographic systems for mass survey of gastroduodenal diseases

	Fluororadiography				Direct Full Size Roentgenography
Apparatus	60 mm. Lens Camera	70 mm. Mirror Camera	100 mm. Mirror Camera	70 mm. Filming of I.I. Output Screen	Full Size Roll Film of X-Ray T.V.
Technical Data in Roentgenography	120 kv. ~ 80 kv. cut	120 kv. ~ 100 kv. cut	120 kv. ~ 110 kv. cut	90 kv. 4 ma. 0.1 sec.	88 kv. 150 ma. 0.1 sec.
Skin Dose in mr	933	612	318	4.4	168

* A human phantom 19 cm. thick at the abdomen was used.

TABLE V

ESTIMATED SKIN DOSE TO THE PATIENT 19 CM. THICK AT THE ABDOMEN DURING VARIOUS X-RAY TECHNIQUES FOR MASS SURVEY OF GASTRODUODENAL DISEASES*

Technique and Devices	Without Fluoroscopy			With Fluoroscopy	
	60 mm. Lens Camera	70 mm. Mirror Camera	100 mm. Mirror Camera	70 mm. Filming of 11 inch I.I. Output Screen	Full Size Roll Film of X-Ray TV combined with 9 inch I.I.
Patient's Skin Dose	900 mr×6 =5,400 mr	600 mr×6 =3,600 mr	300 mr×6 =1,800 mr	5 mr×6 + 900 mr×3 min. =2,730 mr	150 mr×6 + 700 mr×3 min. =3,000 mr

* Assuming that 6 exposures are performed per case for each technique, and duration of fluoroscopy is 3 minutes for the techniques with x-ray television fluoroscopy.

under television fluoroscopy; and (C) direct roentgenography by using full size roll film under television fluoroscopy.

On what basis should we discuss the value of these different x-ray methods? Perhaps there are many discrepancies of opinion according to the basis to which a debater attaches importance. In this respect we believe that evaluation of a diagnostic x-ray method should be on the basis of keeping the value of ratio I/R as large as possible, where I means a quantity of obtainable information and R is a patient dose—if an apparatus is not remotely controlled or imperfect in protection from radiation, the radiation exposure to a radiologist and/or an operator (R') must be added—, although a method to evaluate perfectly the information is not yet established.

We had already proved that diagnostic ability of an apparatus has relation to its detail perceptibility from a practical standpoint.[7] We also gave proof of superiority of the direct roentgenography under fluoroscopy in comparison with the fluororadiography without fluoroscopy concerning the diagnostic ability in x-ray examination of the stomach and duodenum.[7] In addition to that, we had verified in the previous paper that the remote control of a radiographic-fluoroscopic table does not result in deterioration of the diagnostic ability.[5] In consideration of these previous data and the present data on performance evaluation of radiographic systems and patient dose, it may be reasonable to judge the order in superiority of various methods for mass x-ray survey of the stomach and duodenum to be as follows: (1) direct roentgenography, using full size roll film under television fluoroscopy, or fluororadiography using 100 mm. mirror camera; (2) fluororadiography, using 70 mm. mirror camera; (3) filming of an image intensifier output screen under television fluoroscopy; and (4) fluororadiography, using a lens camera.

SUMMARY

A newly developed x-ray television installation, provided with the full size roll film changer which was especially designed for mass survey of gastroduodenal diseases, is described.

The superiority of the direct full size filming under television fluoroscopic control is discussed from a point of view of obtaining more information under less radiation exposure in comparison with the fluororadiographic methods, using mirror or lens cameras and using the filming of an image intensifier output screen.

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