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IN OUR previous paper,[2] we reported the construction and diagnostic application of an x-ray television unit with a vidicon-image intensifier combination system which was first introduced for practical use in Japan. The unit then reported, for all its diagnostic advantages, had several disadvantages. These were as follows:

1. The tilting table for the x-ray television unit was not operated by remote control; hence, operators and physicians were not completely protected from radiation exposure.

2. The image intensifier that was combined with a vidicon camera had only a 5 inch diameter which proved rather unpopular in diagnostic practice in terms of area and speed.

3. The television broadcasting standard with 525 scanning lines showed a rather poor efficiency in transmitting x-ray television signals.

4. An ideal x-ray television unit for roentgen diagnosis should be capable of telefluoroscopy, telefluororoentgenography, telecineroentgenography and remote control direct roentgenography used singly or in combination.

In the present communication the efforts which were made to improve the original x-ray television unit are being reported.

REMOTE CONTROL FLUOROSCOPIC TABLE FOR X-RAY TELEVISION EXAMINATION

In order to utilize the x-ray television system so that images could be observed in a separate radiation-free room, we devised a diagnostic table with full remote control operation (Fig. 1).

Possible Movements of the Fluoroscopic Table. The table is capable of three different types of movements, longitudinal sliding, lateral traverse and up-and-down tilting (Table 1). Since this range of movements offers complete roentgenographic coverage of the desired area, satisfactory gastrointestinal examinations, chest and heart surveys, studies of bones and joints, pyelography, bronchography, cholecystography, myelography and angiocardiography can be carried out.

Focus-Screen Distance. The x-ray tube focus-screen distance is changeable within limits of 80–130 cm. by remote control. The distance of 80–100 cm. is employed for telefluoroscopy, and the longer one for direct spot roentgenography so that undesired enlarged images are eliminated. This procedure is especially useful for examinations of the chest, including bronchography, examinations of bones and joints and for pyelography. The distance between focus and screen is indicated on the remote control panel by a digit system.

Shutter. The conventional shutter allows only a right angle quadrilateral field. The present unit is equipped with an image intensifier for a round visual field. Thus, if this intensifier is employed with the conventional shutter, unfavorable situations are very likely to arise.[3] The use of an image intensifier in its full size would produce exposure of an unnecessary portion of the patient's body. An attempt to eliminate such superfluous exposure would result in a rather limited quadrangular visual field inscribing a circle (Fig. 2). This is apt to cause not only an overexposure of the pa-

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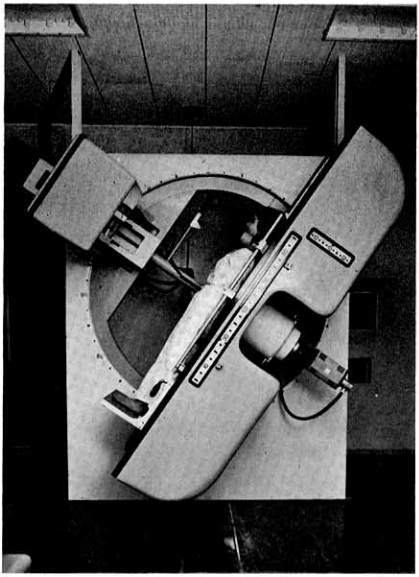

Fig. 1. The diagnostic table which is used with the x-ray television unit for roentgen diagnosis is operated completely by remote control.

tient but also a low viewing efficiency in television due to increase in scattered rays.

Because of these reasons, we designed a new type of shutter for telefluoroscopy, with which we can obtain three shapes of the visual field; (a) a circle 9 inches in diameter, (b) an elongated area with a width of 5 inches (2.5 inches to each side of midline), and (c) a 5×6 inch rectangle. In practice, (a) is used for the chest, heart, gastrointestinal tract and skull examinations as well as for pyelography and bronchography; (b) for examinations of the esophagus, long bones and vertebral column as well as for myelography; and (c) for examinations of the pyloric antrum, duodenal bulb, joints of the extremities and for cholecystography.

During operation, even if the distance

Table I

Movements of the Remote Control Fluororoentgenographic Table

Types of Movements	Range	Speed
Longitudinal Sliding	±50 cm.	3.5 cm./sec.
Lateral Traverse	±12.5 cm.	3.0 cm./sec.
Up-and-Down Tilting	±90°	90°/20 sec.
		90°/40 sec.

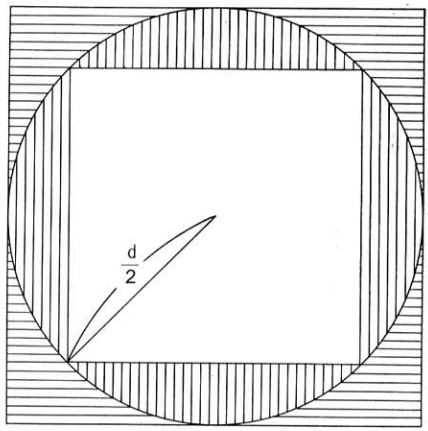

Fig. 2. Diagram showing the area which receives superfluous irradiation (horizontal lines) and the loss of the effective visual field (vertical lines) when the combination of the usual multi-leaf shutter and an image intensifier is used.

In the former, suppose the diameter of the input screen of an image intensifier is d, the ratio of the superfluous field to the entire visual field of an image intensifier is as follows:

$$\frac{d^2 - \frac{\pi d^2}{4}}{\frac{\pi d^2}{4}} \times 100 = \frac{4-\pi}{\pi} \times 100 = 27\%.$$

In the latter, the ratio of the loss of the effective visual field to the entire visual field of an image intensifier is as follows:

$$\frac{\frac{\pi d^2}{4} - \frac{d^2}{2}}{\frac{\pi d^2}{4}} = \frac{\pi - 2}{\pi} \times 100 = 36\%.$$

between the x-ray tube focus and the screen is changed, an automatic control keeps the size of the fluoroscopic field constant. Whenever telefluoroscopy is followed by direct spot roentgenography, the shutter is automatically adjusted for a full-size film. Regardless of the size of film employed, the roentgenographic field is always kept constant, irrespective of a focus-screen distance.

Remote Control Direct Roentgenography. Diagnostic procedures with an x-ray television unit should include not only telefluoroscopy, telefluororoentgenography and telecineroentgenography, but also remote control direct roentgenography, because a full-size film recording is far superior to any other recording method in detail perceptibility. The film size which is used with the present x-ray television system is 14×10, 12×10 and 10×8 inches. As many as 4 full-size roentgenographic films can be held in a magazine on the tilting table as well as a combination of films of different sizes. The size of a film to be used next is indicated on a control panel by a digit system.

Grid. A focussed grid is of a 4.5:1 ratio and 21/cm. density. The grid is fixed in or removed from the visual field by remote control when required, *e.g.*, in chest telefluoroscopy the removal of the grid is advisable to obtain sharpness of image and because of the small dosage desired.

Auxiliary Control Panel in the Examination Room. The operation of the remote control diagnostic table is usually carried out from a radiation-free room which is located away from the examination room. However, in procedures such as catheterization of the cardiovascular system or angiocardiography, physicians and assistants need to remain in the examination room; therefore, a small auxiliary control panel is provided by which to operate the diagnostic table (Fig. 3).

Fig. 3. A photograph showing a diagnostic procedure being carried out in an examination room. A small control panel is provided for the operation of the diagnostic table.

The X-ray Television Installation

Scanning Standard. In the present x-ray television unit, the images which are enhanced by a 9 inch intensifier are picked up by a high sensitivity vidicon camera; hence, the round viewing screen is always used for the vidicon pick-up. If a round visual field were scanned on the usual right angle quadrilateral field having an aspect ratio of 4:3, an appreciable area of the monitor screen would be left useless in transmitting information, as shown in the shaded portion of Figure 4*A*. We therefore introduced a field with an aspect ratio of 1:1, *i.e.*, the square scanning system. Since the resolving power in a horizontal direction is greater because of the square scanning, we utilized 625 scanning lines instead of 525 to preserve the balance of resolving powers between the vertical and horizontal directions. The scanning standard of the present x-ray television system is shown in Figure 4*B*.

Construction and Function. The x-ray television system can be adjusted for various procedures, *e.g.*, telefluoroscopy for the

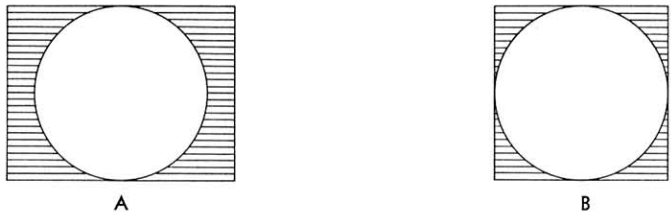

Fig. 4. A diagrammatic comparison between the scanning standard of an ordinary system (*A*) and that of a square scanning system (*B*).

Scanning Standard

	(*A*)	(*B*)
Aspect Ratio	4:3	1:1
Number of Scanning Lines	525	625
Frame/sec.	30	30
Interlace	2:1	2:1

chest and heart, and telecineroentgenography for the cardiovascular system and surgical operations. It can be used for mass examinations, especially of the gastrointestinal tract. It can be utilized for telefluoroscopy, 16 mm. telecineroentgenography, 70 mm. telefluororoentgenography and full film-size direct roentgenography. The diagnostic table is operated by remote control and a vidicon camera pickup allows for a general view of the examination room. The general arrangement of the present x-ray television installation is shown in Figure 5. Diagnostic procedures can be carried out in a control room with complete protection from radiation (Fig. 6).

Telefluoroscopy. Telefluoroscopy is usually done with a 14 inch master monitor at the control desk. However, by using a 17 inch auxiliary monitor in the examination room, diagnostic procedures can also be carried out at the side of the tilting table. In addition, 14, 17 or 21 inch television monitors have been placed in each room of the hospital, where discussion of the telefluoroscopic images is desired. The television transmission and private telephone signaling to other rooms are handled at the main television control desk.

Telecineroentgenography. X-ray images are filmed with a 16 mm. cinecamera and projected on a 14 inch monitor screen which has been installed with its surface turned upwards on a side-table of the control desk (Fig. 6 and 7). Since the pictures are transmitted at 30 frames per second, filming speed in telecineroentgenography is controlled with precision at 15 frames per second by means of a synchronous motor. The footage of the used film is indicated at the control desk by a digit system.

Telefluororoentgenography. The unit is so designed that telefluoroscopic images may be kept on record, which is especially useful when mass examinations of the gastrointestinal tract are performed. It also is capable of serial fluororoentgenography, particularly when the use of 70 mm. roll film instead of 16 mm. cinefilm is desired. A 70 mm. automatic serial roentgenographic camera is installed on the side table of the control desk (Fig. 7). There are two methods of filming: digital spot roentgenography and automatic serial roentgenography at the rate of 1, 2, 3 or 5 frames per second. Automatic serial roentgenography covers 100 frames at maximum. A monitor screen for telefluororoentgenography was installed on the side table in the same manner as was the monitor for telecineroentgenography.

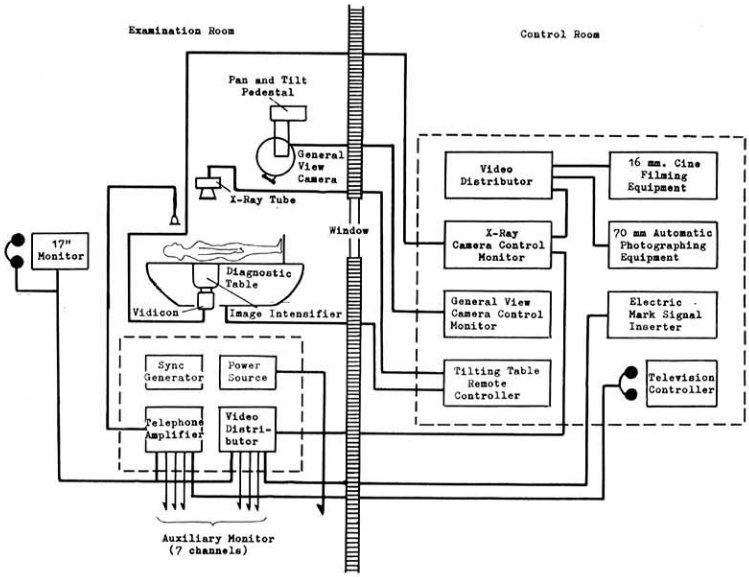

Fig. 5. Schematic drawing of the installation of the present x-ray television unit.

Electric Mark Signal. A triangular mark can be electrically inscribed at any place so that a lesion may be pointed out to observers in other rooms for purposes of discussion or symposia. The mark can be recorded on a 16 mm. cinefilm and/or a 70 mm. spot film.

Monitoring in the Examination Room. A television camera suspended from the ceiling was provided for the purpose of obtaining a general view of the examination room (Fig. 3). Panning, tilting, ascending and descending movements of the vidicon camera are remotely controlled in the con-

Fig. 6. Photograph of the control room of the present x-ray television unit.

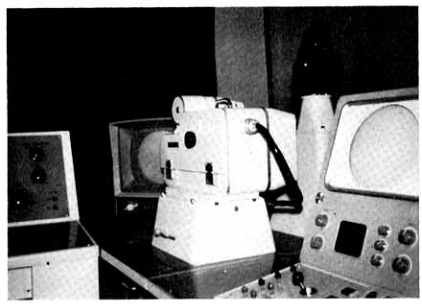

Fig. 7. Photograph of a 70 mm. automatic serial roentgenographic camera for telefluororoentgenography and a 16 mm. cinecamera for telecineroentgenography.

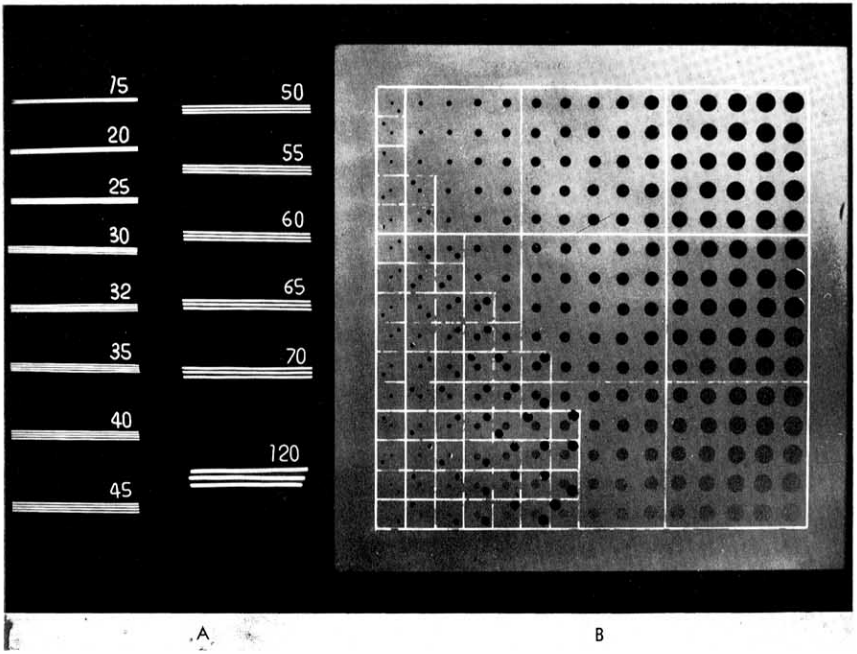

Fig. 8. Copper wire groupings (*A*) and contrast detail phantom (*B*) for testing detail perceptibility.

trol room. Zooming of the televised picture is also possible. A general view of the examination room can be transmitted not only to the control room but to any other room which has been equipped.

DETAIL PERCEPTIBILITY

Measurement of detail perceptibility is accomplished in two different ways, by using: copper wire groupings (Fig. 8*A*) and a contrast detail phantom (Fig. 8*B*). The resolution of the present equipment using copper wires has been studied and compared with that of the previous x-ray television unit (Table II). It was found that the less resolution obtained by using a 9 inch instead of a 5 inch image intensifier was offset by the improved construction of the present television unit. This is not only due to the circuitry and the optical system of the new unit, but also to the adoption of an adequate scanning standard. The employment of a 0.5×0.5 mm. focus size x-ray tube improves x-ray television resolution within a maximum limit of 0.35 mm.

A contrast detail test was performed with a specially prepared phantom (Fig. 8*B*) with interesting results (Table II). Paradoxically, when copper wires are used, the image intensifier is superior to the x-ray television in resolution; however, the former is inferior to the latter when contrast detail is compared. This superiority in low contrast is advantageous in the detection of objects such as stones in a gallbladder or hazy densities in the pulmonary fields. In this respect, Feddema[1] seems to have an opinion similar to ours He cites an instance of gallstone which was detected by x-ray television in the absence of visualization when an image intensifier was used

Table II

COMPARISON BETWEEN THE DETAIL PERCEPTIBILITY OF THE PRESENT X-RAY TELEVISION SYSTEM AND THAT OF THE PREVIOUS ONE[2]

Method*	Diameter of Discernible Wires (mm.)	Depth (h) and Diameter (d) of Smallest Visible Holes (mm.) d ≒ h.
Conventional Fluorescent Screen	0.5	4.4
5 Inch Image Intensifier (Philips)	0.25	—
5 Inch Image Intensifier + Vidicon Camera	0.4	—
9 Inch Image Intensifier (Philips)	0.3	2.4
9 Inch Image Intensifier + Vidicon Camera	0.4 (0.35**)	1.8

* Focus-screen distance: 90 cm.
Focus size of the roentgen-ray tube: 1.0×1.0 mm.
** The detail perceptibility when a 0.5×0.5 mm. focus is employed.

TECHNICAL DATA AND DOSE FOR DIAGNOSIS WITH X-RAY TELEVISION

The technical data, patient skin doses and back scatter in telefluoroscopy, telecineroentgenography and gastrointestinal telefluororoentgenography of the present x-ray television unit are shown in terms of kilovoltage-milliamperage in Table III, compared with those of conventional fluoroscopy. It is evident that there is an appreciable decrease in patient dose when the x-ray television system is used. It must be re-emphasized that neither telecineroentgenography nor telefluororoentgenography requires more than the dose received during telefluoroscopy. In diagnostic procedures, the technical data for exposure and patient dose when remote control direct roentgenography is performed with the x-ray television unit are the same as those obtained with full size direct routine roentgenography. This fact permits use with comparative safety to the patient.

Table III

PATIENT SKIN DOSE IN TELEFLUOROSCOPY OF GASTROINTESTINAL TRACT COMPARED WITH CONVENTIONAL FLUOROSCOPY

Thickness of Abdomen	Telefluoroscopy			Conventional Fluoroscopy		
cm.	kv.	ma.	Skin Dose (r/min.)	kv.	ma.	Skin Dose (r/min.)
14	52–60	2–2.5	0.54–0.88	72	3	3.20
16	55–68	2–2.5	0.58–1.10	76	3	3.50
18	60–70	2–2.5	0.75–1.24	80	3	3.85
20	62–73	2–2.5	0.87–1.44	84	3	4.40
22	65–75	2–2.5	1.00–1.60	88	3	4.80
24	65–75	2–2.5	1.07–1.70	92	3	5.30
26	65–80	2–2.5	1.10–1.98	96	3	5.50
28	67–82	2–2.5	1.27–2.17	100	3	5.75
30	70–85	2–2.5	1.45–2.48	104	3	6.00
32	80–95	2–2.5	1.94–3.25	108	3	6.26

Focus size of the roentgen-ray tube: 1.0×1.0 mm.
Filter: 1.6 mm. Al.
Grid: {X-ray television—4.5–21/cm. / Conventional fluoroscopy—6.5–24/cm.
Focus-screen distance: 90 cm.
Field size: {X-ray television—23 cm. circle. / Conventional fluoroscopy—23 cm.×23 cm. square.

Table IV

REVISED CLASSIFICATION OF THE ORGANS OR REGIONS OF THE BODY ACCORDING TO THE EASE OF FLUOROSCOPY USING X-RAY TELEVISION

Ease of Fluoroscopy	Organs or Regions (nature of examination)	Direction of Roentgen-Ray Beam
	Esophagus and gastrointestinal tract (oral method)	Anteroposterior, oblique
	Sigmoid colon and large intestine (barium enema)	Anteroposterior, oblique
	Trachea and bronchi (bronchography)	Anteroposterior, oblique and lateral
	Heart and aorta (plain)	Anteroposterior, oblique
Extremely Easy	Spinal canal (myelography)	Anteroposterior, lateral
	Pelvis, calyces, ureter and bladder (intravenous and ascending pyelography)	Anteroposterior
	Lung	Anteroposterior, oblique and lateral
	Bones and joints of extremities	Anteroposterior, oblique and lateral
	Vertebral column	Anteroposterior, lateral
	Hip joint	Anteroposterior
Easy	Gallbladder (cholecystography)	Anteroposterior, oblique
	Splenic and portal veins (percutaneous splenoportography	Anteroposterior
Rather Difficult	Heart and aorta (angiocardiography)	Anteroposterior, oblique

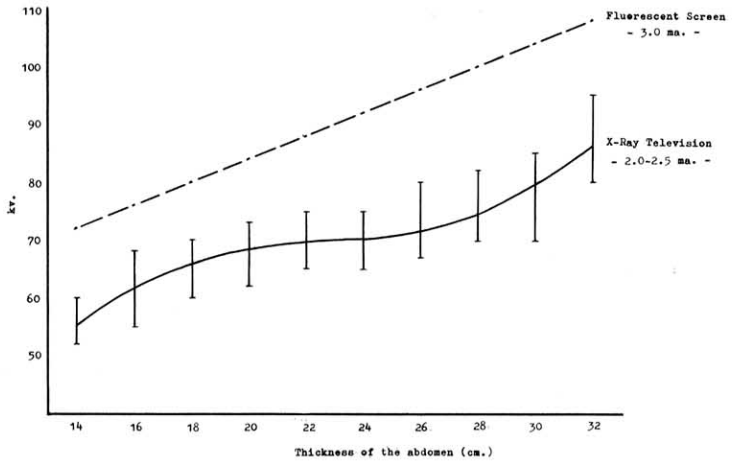

Fig. 9. Technical data in telefluoroscopy of gastrointestinal tract compared with those in conventional fluoroscopy.

DIAGNOSIS WITH X-RAY TELEVISION

The chief advantage of x-ray television diagnosis is that, in examinations where contrast material is used, the organs are easily studied and without radiation exposure to the radiologist. In this regard, a revision has been made in the classification of ease of fluoroscopy which was presented in the authors' previous report[2] (Table IV). The term "difficult" no longer appears since most of the organs or regions have come to be within an "easy" or "extremely easy" x-ray television scope. The thickness of the abdomen no longer interferes with the clearness of the fluoroscopic images of the alimentary tracts, gallbladder, lumbar spine and urinary tract. The examination of the heart and large vessels by angiocardiog-

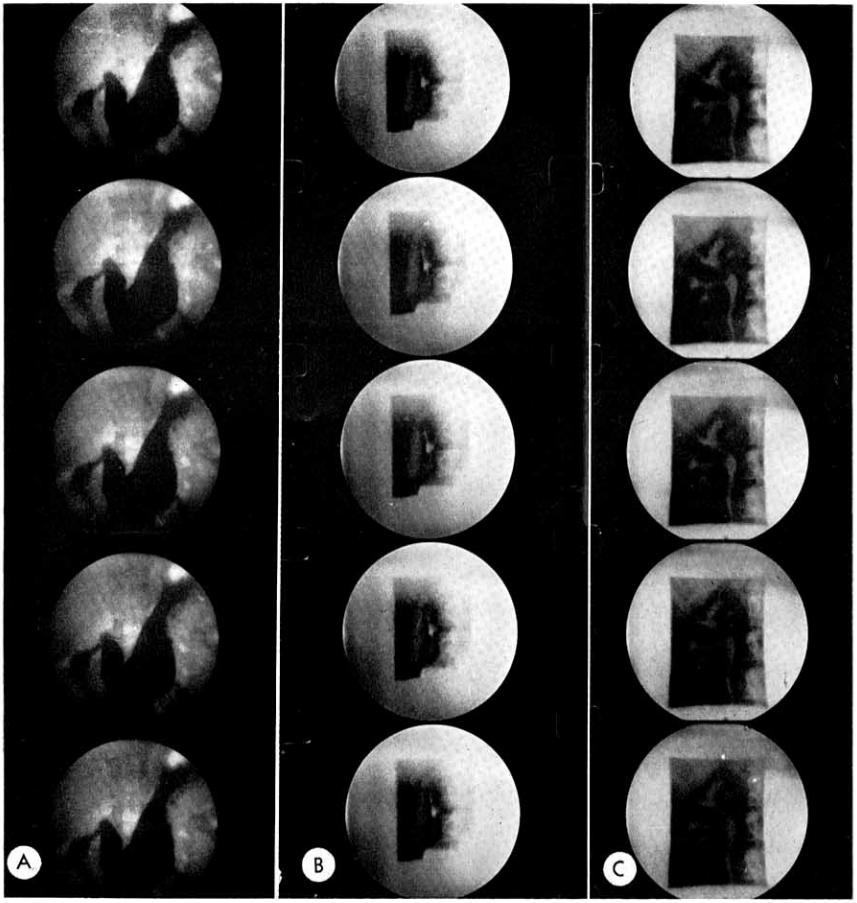

FIG. 10. Telecineroentgenograms showing: (*A*) gastrointestinal tract; (*B*) a gallbladder in cholecystography and (*C*) calyces, pelvis and a ureter in intravenous pyelography.

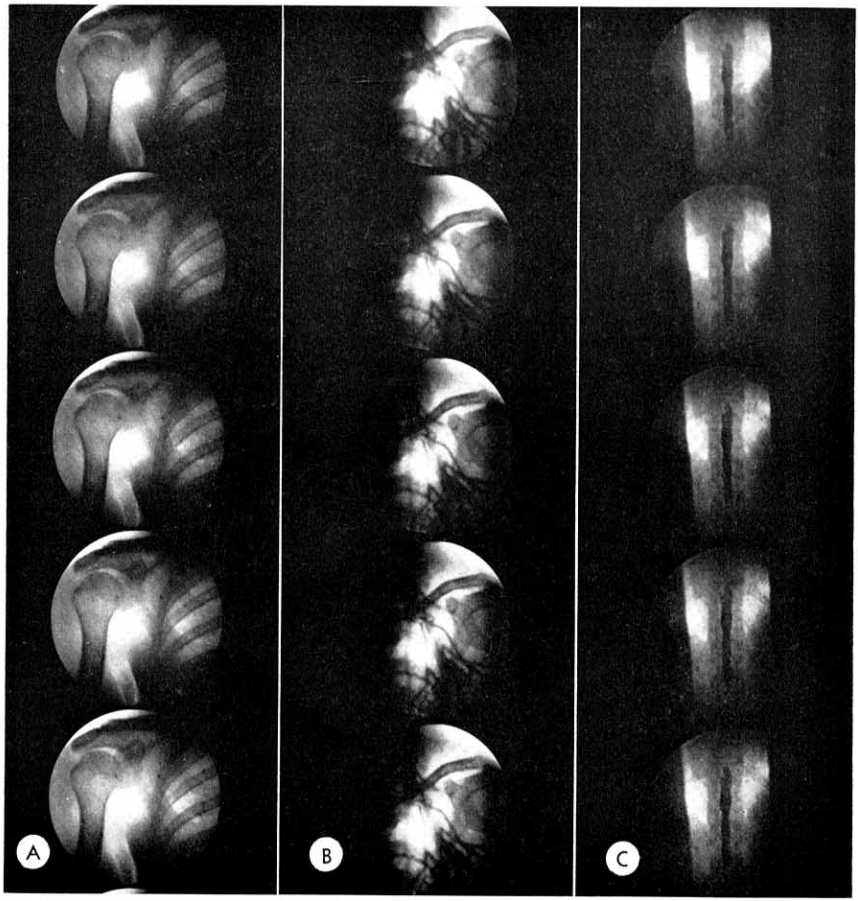

Fig. 11. Telecineroentgenograms showing: (*A*) a shoulder joint; (*B*) collateral veins in venography; and (*C*) a spinal canal in myelography.

raphy is, however, newly classified as being "rather difficult."

The relationship between the thickness of the abdomen and the voltage-milliamperage by which clear telefluoroscopic images of the alimentary tract are obtained is shown in Figure 9 and a comparison is made with conventional fluoroscopy.

Figures 10, *A*, *B* and *C* and 11, *A*, *B* and *C* are telecineroentgenograms and Figure 12, *A* and *B* shows indirect telefluororoentgenograms made by using the 70 mm. automatic serial roentgenographic camera.

Since the beginning of 1961, the authors have employed the present improved x-ray television system instead of conventional roentgenography in all instances of intravenous pyelography, myelography, venog-

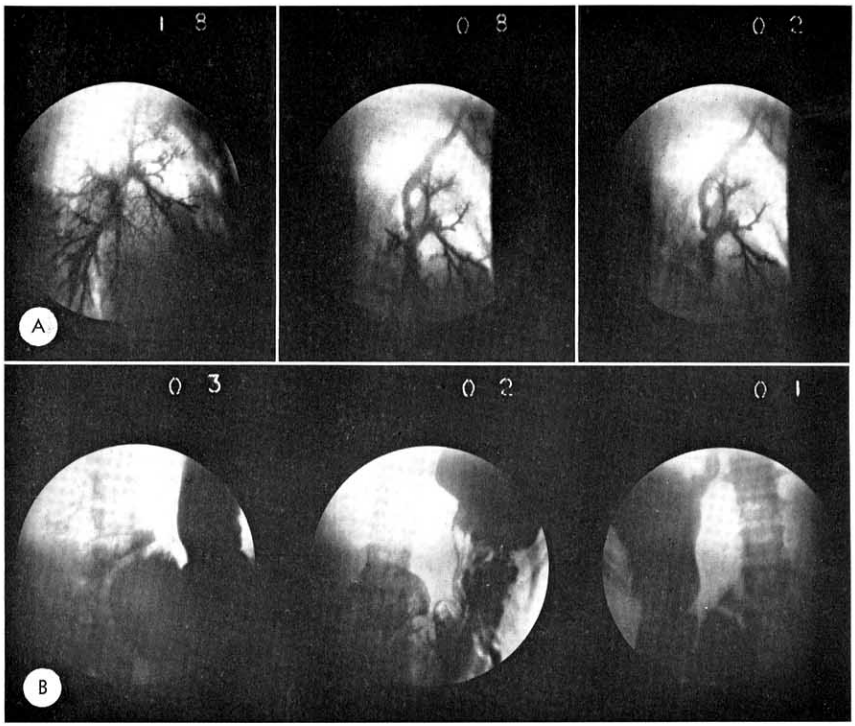

Fig. 12. Telefluororoentgenograms (70×70 mm. size) showing: (*A*) a bronchial arborization in oblique bronchography; and (*B*) a stomach and duodenum, *en face*.

raphy including splenoportography and bronchography and in one-third of the cases requiring gastrointestinal series including cholecystography. It is hoped that with the acquisition of a sufficient number of x-ray television units, all gastrointestinal examinations will be performed in this manner.

SUMMARY

A report is presented of the construction problems, diagnostic application and efficiency of an improved x-ray television system with a remote control fluoroscopic table and a comparison is made with the previously described one. Roentgen diagnosis by means of this unit is discussed.

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