AN X-RAY KYMOGRAPH AS A METHOD FOR STUDYING THE PHYSIOLOGY OF THE GASTRO-INTESTINAL TRACT

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There is no doubt that one of the most physiological methods of studying functional changes of the gastro-intestinal tract is by the use of x-rays. X-ray cinematography has many undoubted advantages, but the method of x-ray kymography, just like x-ray methods on the whole, has not been sufficiently appreciated.

It may be applied as a one-slit or as multi-slit methods. The principle of the single slot device was proposed in 1911 by Sabat. It consists in recording the movements of the organ studied by x-rays which pass through a slit in a fixed lead plate, so as to form an image on an x-ray screen. During the exposure the x-ray film moves together with the cassette relative to the lead plate.

In the single-slit method, an extended curve, the x-ray kymogram is obtained on the film (with various multiplications, several curves may be obtained); the trace represents a graphic recording of the movements of a selected point of the object studied. This classical method of single-slit "extended " x-ray kymography gives no image of the organ as a whole, and records the movement only of certain chosen boundary regions.

Stumpf in 1928 developed the multi-slit method. In it, beams of x-rays pass through several parallel slits in a lead grating before they form an image of the organ on the film [8].

Two kinds of multi-slit X-ray kymograms may be obtained, the continuous and the stepped. If during the exposure the cassette moves with respect to the fixed grating, then on the film will be recorded the movement of as many corresponding points at the boundary of the object under study as there are slits in the grating, and these points are separated from each other by the thickness of the kymograph plate. In this way the silhouette of the organ presents a stepped appearance. If the x-ray kymogram is obtained by a moving grating and a motionless x-ray film, it is called continuous. In such an x-ray kymogram, the object is not distorted, because the movements of all the boundary forming points are recorded continuously and successively on the film.

X-ray kymography was first applied clinically for the objective study of the functional condition of the cardio-vascular system. Subsequently it was applied to the respiratory system, and finally to the gastrointestinal tract.

In analyzing x-ray kymograms, it is usual to take into account the shape, size, and number of peaks. The amplitude of the peak is determined by the perpendicular on to two parallel lines, of which one connects all the lateral apices of the peaks, and the other the medial apices. It is easy to make a comparative graphic representation on the x-ray kymogram incomparably more precise than is a subjective evaluation using ordinary x-rays, or even x-ray cinematography.

The possibility of comparing and rapidly changing over from x-ray examination to x-ray recording, and then to x-ray kymography makes it possible to record simultaneously functional changes in different parts of the stomach and intestine. X-ray kymography enables the shape, position, and dimensions of parts of the digestive tract to be investigated, and gives information on the nature of their changes in various pathological conditions and in response to physiological actions. A study of the height, shape, and number of peaks on the x-ray kymogram enables peristalsis and the tone of the different parts of the gastrointestinal tract to be studied.

We have used the 1955 model of the Soviet universal multi-slit x-ray kymograph made by the factory "Rentok". It has three alternative gratings having distances of 6, 12, and 36 mm between the slits, and is supplied with a rotating disc, which greatly increases its possible experimental applications.

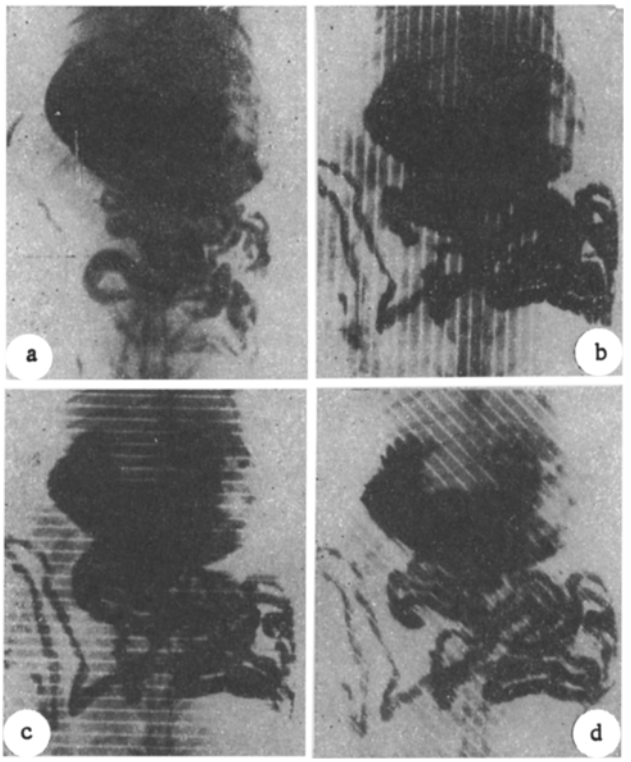

Fig. 1. X-ray picture and x-ray kymogram of the abdominal cavity of a healthy rabbit.
a) X-ray obtained 10 minutes after introduction of a contrast substance into the stomach; it fills the stomach, and the first few loops of small intestine; voltage 55 kv, current 60 ma, exposure time 0.4 seconds; b) x-ray kymogram, grating step 6 mm, motion perpendicular to the body of the animal; peaks indicate the depth of peristaltic contraction of the pylorus; exposure 7 seconds, voltage 45 kv, current 60 ma; c) ditto with a grating movement along the body of the rabbit, conditions of exposure the same as before; d) ditto, after rotation of the grating through 45°; the undistorted peaks of the pyloric portion of the stomach are well shown, and their amplitude reaches 1 cm; peristaltic movements of the different loops of the small intestine can be seen.

In studying the shape of the digestive organs, in some cases it is not possible to make out all that is required from two mutually perpendicular projections, because the greatest amplitude of the peaks occurs when the boundary of the object studied is displaced perpendicular to the movement of the grating. A rotation of the apparatus through 45° enables a better study of peristalsis in the pyloric division of the stomach and in many parts of the intestines to be made. In experiments on rabbits we used chiefly a grating having a step of 6 mm, particularly when the movement occupied a period of 6-7 seconds. An image is then obtained having a sufficient number of peaks from which the rate, frequency, and amplitude of the peristaltic waves may be determined (Fig. 1).

A contrast substance consisting of a 1:2 suspension of barium sulfate in water was introduced through a tube directly into the stomach. To prevent the tube being bitten a wooden plate bearing a hole in the center through which the tube passed was introduced into the rabbit's mouth. X-ray kymography was undertaken after the normal x-ray pictures had been made. For this purpose the animal lay prone, and the x-ray kymography was positioned dorsally.

This method enabled us to study functional changes in response to various drugs (morphine hydrochloride carbocholin, adrenalin, etc.), and the effect of damage to the hind limbs.

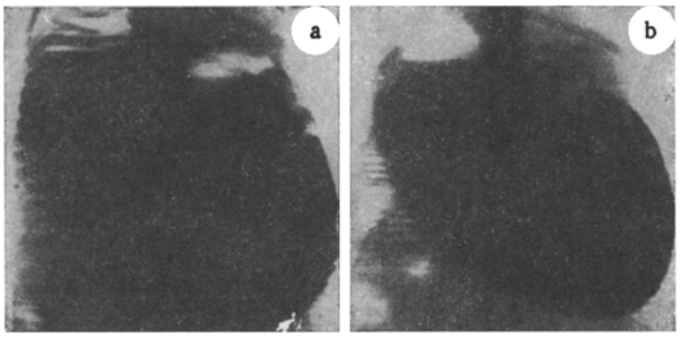

Fig. 2. X-ray kymograms of the rabbit stomach. a) After injection into the stomach of a contrast substance; amplitudes of the waves of the pyloric division of the stomach shown on the kymogram is about 0.9 cm; b) 2 minutes after damage to the hindfoot, and 3 minutes after the previous kymogram had been taken there is a marked reduction in the extent of the peristaltic movements.

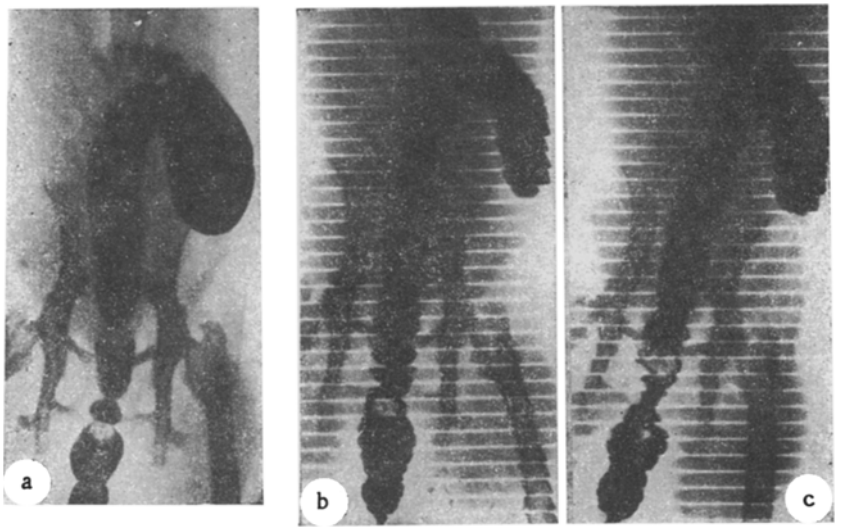

Fig. 3. X-ray picture and x-ray kymogram of the abdominal cavity of a rabbit. a) X-ray picture obtained after introducing a contrast substance into the large intestine; b) x-ray kymogram obtained 30 seconds after the x-ray picture; c) x-ray kymogram obtained one minute after damage to the hindfoot of a rabbit and 3 minutes after the previous x-ray picture had been taken; increase of the waves indicating peristaltic excursions of the large intestine can be seen, as well as spastic contraction of certain parts indicating an increased tone.

It is well known how widespread is the clinical method of making an x-ray study after introducing a contrast substance as an enema, and how effective it is in diagnosing pathological (particularly anatomical) changes. Unfortunately the possibility of recording functional changes has not been sufficiently appreciated. Nevertheless it is evident that the reaction of the large intestine to the introduction of a suspension of barium sulfate by this unusual route, will vary according to the functional condition of the intestine. One author [7] has drawn attention to this experimentally important point. Even at that time (1936) it was shown that the time, nature, and rhythm of the emptying of the bowel at defecation were determined by the tone and motor function of the intestine. Subsequently we perfected the method of x-rays combined with the giving of an enema, which at the present time takes the following form.

Without any special preparation, the animal is fixed to a stand. A catheter is inserted into the rectum, and in one minute 50 ml of contrast medium is injected from a 100 ml syringe. A clamp is then placed on the free end of the catheter for ten minutes. During this time one x-ray picture and two x-ray kymograms are obtained. The catheter is then removed, and exposures are expected at intervals of 15, 30, and 60 minutes, though if intestinal tone is reduced, further exposures are made until the bowel has been completely emptied. Before each exposure an examination is made or a screen to determine the amount of contrast substance remaining, and as a control over the animal's position (Fig. 3).

Our experience enables us to recommend the method of the x-ray kymogram for animal experiments.

SUMMARY

X-ray kymography enables the shape, position, and size of the different parts of the digestive tract and certain physiological effects to be demonstrated, and in addition reveals changes in various pathological conditions. The height, shape, and number of waves indicate both peristaltic movements and tone. A description is given of the method of preparing the animal for the investigation. A description is given of a method for studying changes of the physiological condition of the normal rabbit gastro-intestinal tract; in addition, several effects are described.

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