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With Description of Rapid Film-changing Device

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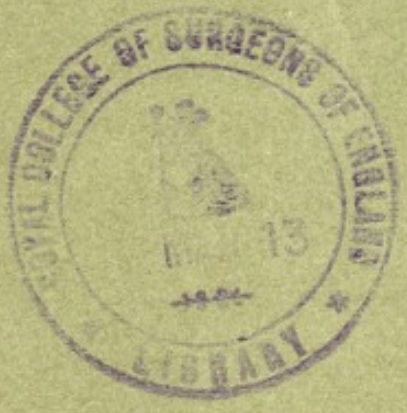

THE GASTRIC MOTOR PHENOMENA DEMONSTRATED WITH THE PROJECTING KINETOSCOPE

BY LEWIS GREGORY COLE, M D., NEW YORK

Early last spring, through the invitation of Dr. Wm. G. Lyle, I had the pleasure of seeing the Roentgencinematographic films which had been made by Rosenthal, projected on the screen. These films were later reproduced to illustrate an article by Kaestle, Rieder and Rosenthal, entitled, "Bioroentgenography of the Internal Organs," published in the Archives of the Roentgen Ray, June, 1910. An immense amount of credit is due these men for accomplishing a feat, which a few years ago, seemed visionary to the most ardent radiologists.

In the first paragraph of this article, the authors justly called attention to the fact that a true cinematographic reproduction of the movements of an organ is made up of a series of radiograms taken of successive phases of a single cycle, and that when the successive phases are made up of different cycles, no logical claim should be made to the term "Roentgencinematography." Later in their article, they stated that twelve of the radiograms were made during a single respiratory phase of twenty-two seconds, which, they say, is the normal duration of a single peristaltic contraction.

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The term single peristaltic contraction of the stomach is so new that it may be well to consider its meaning. I believe it should be applied to the formation and duration of a single antrum or the terminal wave. And it seems to me that a better term would be "single peristaltic cycle." We should be careful not to confuse this with the progression of a contraction from its origin near the fundus to its termination at the pylorus.

While the duration of a peristaltic cycle (as above described) varies within wide limits, the average duration is not over two or three seconds. My statement for this is based on repeated fluoroscopic examination and a few double exposures on a single plate, making two exposures of one-tenth of a second each about one-fourth of a second apart. These plates show that the peristaltic contraction travels along the greater curvature about one-fourth inch in one-fourth of a second, or at the rate of an inch per second. Therefore, the duration of a single peristaltic cycle as described above, does not exceed two or three seconds; and the time it takes any individual contraction to pass from the fundus to the pylorus is not over ten seconds. I shall lay no claim to the term "Roentgencinematography" until I have succeeded in obtaining at least four radiograms per second.

After seeing the wonderful set of radiograms made by Rosenthal, projected on the screen, I realized the scope of this method of diagnosis and went to work immediately to produce it. No information whatever was then available concerning his technique, etc., whether an intensifying screen was used or what sort of plate changing device was adopted. My first efforts were without a screen, with a double coated sigma plate, making one-half second exposures. This was too long in the majority of cases, to obtain the necessary detail. With one-fourth second exposures, while we obtained a faint image of the stomach, the plates lacked sufficient density for reproduction. At about this time my attention was called to the calcium tungsten screen which proved to be the most

important of all the factors that culminated in the production of this type of radiograms. Provided it be properly dusted, this screen shows so little grain that the only way its use can be detected is by a slight blur in the bony structure. The density of the plate thus became increased from ten to twenty times, and the fact that it allows the use of a soft tube accounts for the increased contrast in these plates. Not being able at that time to obtain any information concerning the plate-changing device which was used by Rosenthal, I designed the principal parts of two plate and film changing devices. One of these very closely resembles the one later described by Kaestle, Rieder and Rosenthal, and the other I will demonstrate to the Society.*

Technique:—The preparation of the patient is similar to that for an ordinary radiogram of the stomach. The clothing of the patient, who comes in the fasting condition, is removed from the abdomen, and markers are placed over the umbilicus and ensiform process. Two glasses of buttermilk and two ounces of bismuth subcarbonate are then given by mouth. The patient lies, or stands, with the abdomen flat against the opening of the box, and by fluoroscopic examination the stomach is centered so that it is over the opening in the box. The tube, preferably a seasoned one, having a focal point one-eighth inch in diameter, backing up a four-inch parallel spark, without requiring regulation, is arranged about twenty inches from the film and diaphragmed so that it just covers the opening in the box. Exposures of about one-tenth second are made, passing from 40 to 50 M. A. through the tube. During the intervening nine-tenths second, between this and the next exposure, the film is changed as described above. A fluoroscopic examination can be made during the time all these exposures are under way. The films are then developed on a rack, similar to the method used for the regular cinematographic films. The regular cinematographic exposures are then made of these films, care being taken

*Note—I am indebted to Dr. Harry Waite for material assistance in the designing and construction of this apparatus.

to have them centered according to the disks, which appear as markers. About two or three cinematographic exposures are then made of each film. This gives a duration to the peristaltic contraction which corresponds approximately to the actual duration of the contraction, but unfortunately, in the films I have to demonstrate, the radiograms were not sufficiently numerous to give a perfectly smooth appearance to the contractions.

In order to understand the peristaltic contraction of the stomach as observed in a series of instantaneous radiograms, it might be well to have some conception of a fairly normal contraction before investigating the abnormal. Mindful of the chaos, however, which has existed in the minds of physicians in general, and radiologists in particular, since Rieder gave his first bismuth meal and proved that the majority of stomachs do not lie in the abdomen in the old text-book fashion, I hesitate at the mere mention of normal peristaltic contraction. The description of the normal peristaltic wave was avoided by Kaestle, Rieder and Rosenthal, who refer in their article to the peristaltic contraction of abnormal stomach. This is a perfectly fair statement, because the girl whom they radiographed undoubtedly had a normal stomach. But in view of the variation in size, shape and position of the stomachs that functionate in a normal manner, so far as can be determined by all other methods of examination combined, the peristaltic contractions of these stomachs may be assumed to vary in even wider limits with the quantity and quality of the food and the mental condition of the patient.

The series of radiograms which I am about to show and the fluoroscopic observations, which the construction of my table allows me to make, immediately before, during, and after each exposure, lead me to confirm to a large degree the observations made by Kaestle, Rieder and Rosenthal, whom I shall quote as follows:

"Our investigation shows that during digestion there is no such division of the stomach into two distinct parts, and that a strongly differentiated antrum pylori in the old acceptance of the term does not exist. As our tracings show,

the formation of the new antrum does not commence at the spot where the final emptying of the stomach occurs, and is, therefore, not a mere relaxation of the contracted walls. If we adhere to the idea of an antrum pylori, then it is necessary to speak of two such antra existing side by side and at the same moment. We must speak of an old and a new antrum, as we have done for clearness of expression in the foregoing pages. As the old antrum disappears a new antrum is developed from the wall of the body of the stomach. This new antrum passes pylorusward, and ultimately exactly takes the place of the old antrum, whilst another new antrum begins to form. Moreover, if we wish to adhere to the term, our idea of the antrum pylori must be modified. In our opinion there is no true antrum pylori, any more than there is a sphincter pylori, in the sense of the older observers; 'What we see in the regio pylorica is an increase in the energy of the gastric peristalsis and an increase in the height and depth of the wave summits and depressions.'"

On the other hand, my observations have confirmed to a large degree Gradel's criticism of Kaestle, Rieder and Rosenthal's article. Gradel states that a large number of observations have shown him, that, at any rate, these observations are by no means constant I do not know whether these observations made by Gradel are based on fluoroscopy or a series of radiograms. Personally, I have been unable to detect these small contractions along the wall of the body of the stomach in a fluoroscopic examination, although a radiogram, made at the same instant when I observed the stomach fluoroscopically, shows them to be present. But in some of the cases, even the radiograms have failed to show the presence of these contractions.

Figure I shows four radiographs of a stomach in different stages of digestion. In this case, when the stomach was first filled with buttermilk and bismuth, there was little or no attempt at peristaltic contraction (A). In the next radiogram of this case (B), made about three or four minutes later, there was a very slight peristaltic contraction. This contraction was so slight as to be hardly discernible on fluoro-

scopic examination. Radiogram (C) shows a peristaltic contraction which was caused by external stimulus, namely: an attendant slapping the patient just before the exposure was made.

Instantaneous radiograms were made at intervals, and the fourth radiogram of the set (D) was made about one-and-a-half hours after the administration of the buttermilk and bismuth. When the stomach had partly emptied itself, these peristaltic contractions became more active, or at least were more clearly demonstrated on the plate. This series of radiograms shows that when a stomach is over-distended, the peristalsis is not so active as when it is partially filled. Whether, aside from the diminished quantity in the stomach, the production of hydrochloric acid is a factor in the increased peristaltic action of this particular stomach or not, I am not ready to state, but I believe this to be the case on the basis of other observations.

Figure II. This series of radiograms demonstrates the motor phenomena of digestion as described by Holzknecht in the Munchener medizinische Wochenschrift, and quoted by Kaestle, Rieder and Rosenthal in Archives of the Roentgen Ray of June, 1910.

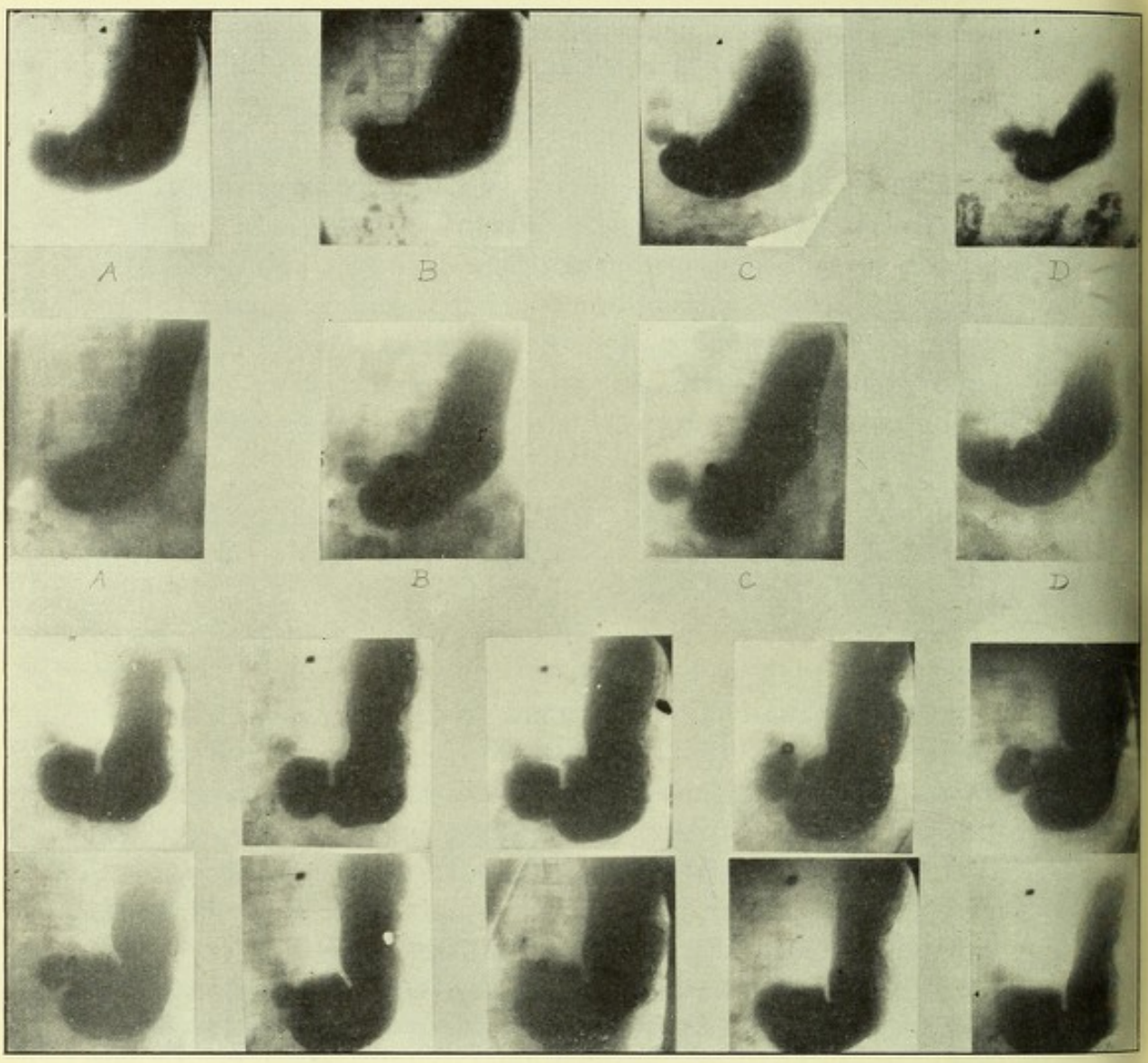
"The motor phenomena of digestion, as seen by Roentgenoscopy, are as follows: While there is no active movement to be seen in the cardiac portion of the stomach, the lower portion of the greater curvature exhibits deep contractions. These depressions travel towards the pylorus, gradually getting deeper during their passage, till they get their maximum depth at the sphincter pylori, a point three or four fingers' breadth above the pylorus. The maximal point of depression is characterized by the length of time it remains in a state of tonic contraction, and by the fact that the contractions here are the most energetic of any part of the stomach wall.

"Opposite to this deep constriction of the greater curvature appears a similar depression of the lesser curvature, of almost equal depth. There is no movement of the lesser curvature visible in the upper part of its contour. Eventually the

depression of the smaller and that of the greater curvature meet, so that on the screen there is seen a clear line between the shadow of the contents of the corpus and of the antrum. Soon afterwards the shadow of the antrum disappears, its contents being emptied into the duodenum by a process of concentric contraction.

"The constriction three or four fingers' breadth above the pylorus, mentioned above, has the effect of a sphincter antri which periodically cuts off the antrum pylori from the body of the stomach. The circular constriction at this point is comparable in breadth and extent with the pylorus itself. The button-like reduction of the antrum is brought about by a process of concentric contraction. It is doubtful, however, whether there is a simultaneous peristaltic movement of the circular contraction toward the pylorus, or whether the circular depression remains stationary and the evacuation is brought about by a contraction of the longitudinal fibres alone."

Figure III. Seventeen radiograms have been made of this case and all show the peristaltic contraction in various stages, ten of which are selected for reproduction. This set of radiograms corresponds with the type of contraction which Kaestle, Rieder and Rosenthal consider normal. There are two distinct peristaltic contractions which may be seen in all the plates in different stages. The formation of the new antrum as the old one disappears is clearly demonstrated in this set of radiograms. These have been made so recently that there has not been time to center them properly and to prepare cinematographic films; if this had been done, the cinematographic reproduction would have shown a very much smoother and perhaps more normal peristaltic action of the stomach than the one which I am about to show. This set of radiograms, however, studied in detail and individually, affords the diagnostic aid which is required and proves that a projecting apparatus is not necessary for diagnostic purposes. Every one of the seventeen plates prepared in this case shows the detail which was present in the ten radiograms reproduced.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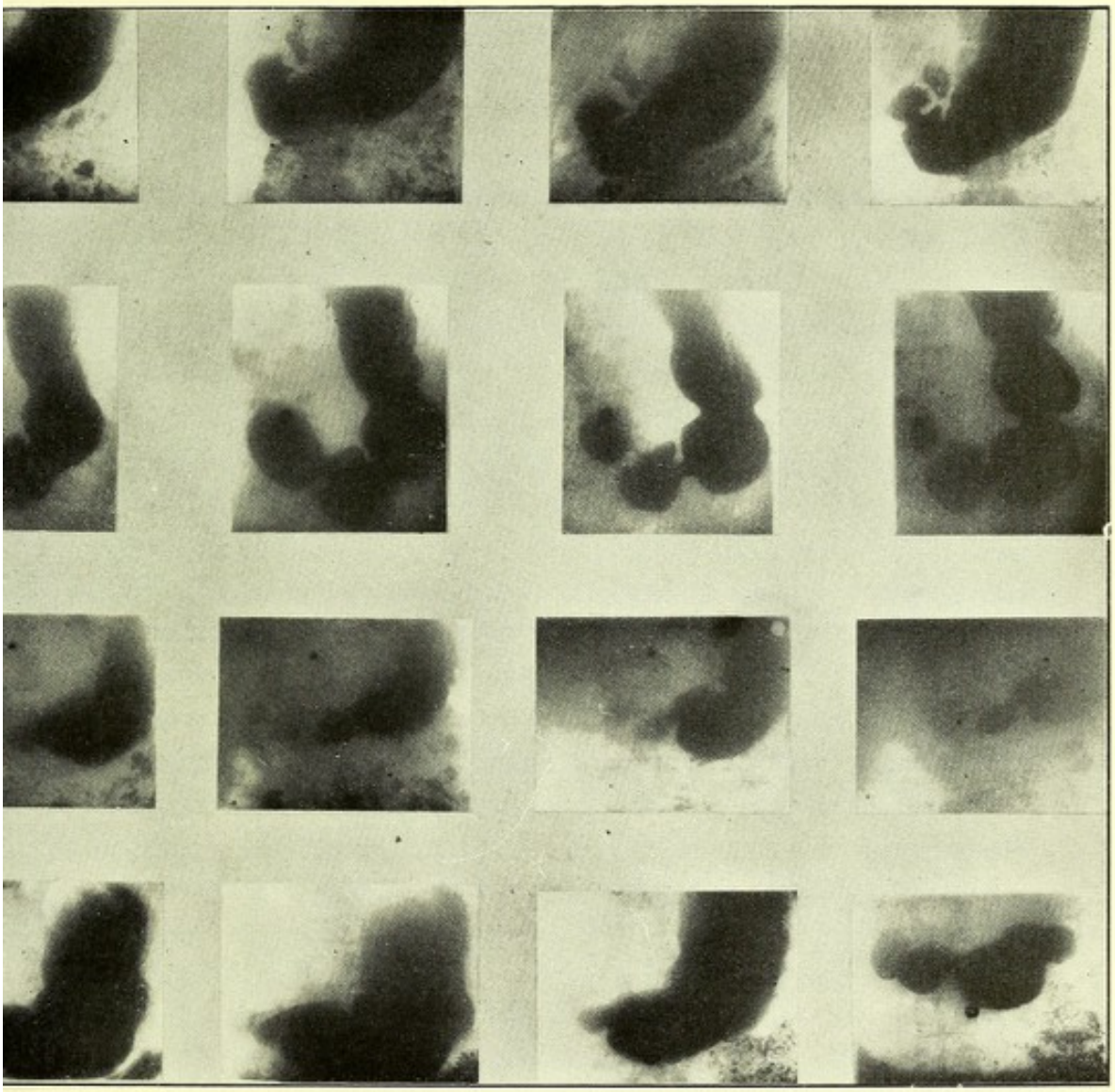


Holzknecht refers to one peristaltic contraction, Kaestle, Rieder and Rosenthal to two peristaltic contractions, but there are many cases in which three or even four distinct peristaltic contractions can be demonstrated by this manner of examination.

Figure IV demonstrates a one-and-a-half wave type of peristalsis which is intermediate between the one-wave type described by Holzknecht and the two-wave type described by Kaestle, Rieder and Rosenthal. Studying this case fluoroscopically, one would observe only the one well-marked peristaltic contraction and consider it as the type described by Holzknecht, but when studied radiographically there is clearly discernible a small secondary wave on the lesser curvature and Kaestle, Rieder and Rosenthal would claim it as a slight modification of their type of motor phenomena.

Figure V shows one of these cases where four distinct peristaltic contractions are demonstrable. The radiograms, unfortunately, do not include the entire fundus, but the peristaltic contractions are seen on the greater and lesser curvatures, well up toward the fundus of the stomach. These contractions become deeper as they move pylorusward and in radiogram (C) Figure IV, we have the button-like contracted antrum, the formation of a pre-antrum, and two or possibly three antra yet to come. I think these plates particularly emphasize the point referred to by Kaestle, Rieder and Rosenthal, namely, that it is unwise to preserve the term, "antrum pylori," and advisable instead to interpret what is seen in the region antrum pylori as an increase in the energy of the gastric peristalsis and as an accentuation in height and depth of the wave summits and depressions, only that the well-marked contractions in this case are not limited to the pyloric region. I do not claim that this last case was normal, being aware that it was a case of hyperchlorhydria. The peristaltic contraction is certainly more active than usual, bearing out the observations of Brauning regarding the relation between the tone of the stomach and its production of hydrochloric acid.

It seems to me that the simplest way is to consider the stomach as a sac in which there may be all degrees of peristaltic contractions, passing pylorusward. In extreme cases of atony of the stomach, the contractions are so few and so slight as to be indiscernible, either fluoroscopically or radiographically. Where there is more tone to the stomach, a single peristaltic contraction occurs, passing pylorusward, and when there is still more tone to the stomach, two contractions are demonstrated by instantaneous radiography where only one was discernible fluoroscopically. Progressively, a still better tone to the stomach is associated with three or even four contractions and waves, or antra. I believe that the most common is the stomach with two contractions and two waves or antra, but am not prepared to state that a single wave on the one hand, or three or even four waves on the other are beyond the normal limitations.* This point, I think, can only be decided by making a great number of radiograms of cases free from gastric symptoms, and after all other tests have shown the function of the stomach to be perfect. While these cases are interesting from a physiological and scientific standpoint, the particular application of this method of examination depends on a study of the interruptions of the contractions or waves as they progress pylorisward. Considering only the body of the stomach, Figure V illustrates a stomach of the two-wave type of motor phenomena with deep contractions like those described in Figure III, but when they are about two and one half inches from the pylorus they suddenly cease both on the greater and lesser curvatures. The failure of the pyloric end of the stomach to expand and contract in proportion with the body and cardiac end indicates some pathological process which prevents the normal dilatation of this portion of the stomach. There is, however, a slight variation in the lumen of the pyloric end of the stomach and the deepened rugae indicate that this is caused by adhesions encircling this portion of the stomach. This case was verified by operation and

*Note—More recent observations have shown that the stomach with three or four waves is the most common.

the entire pyloric end of the stomach was encircled by extensive adhesions.

Figure VI represents a similar condition where there are well-defined peristaltic waves along the lesser curvature until they reach a point about three and one half inches from the pylorus; here they cease suddenly and there is a perfectly flat surface which corresponds in shape and position with the lower surface of the liver. On the greater curvature the contractions become much deeper as if trying to compensate for their absence on the lesser curvature.

This case has not, to my knowledge, been verified by operative procedure, but the history of an operation on the gall-bladder through this route tends to confirm the radiographic diagnosis.

The radiograms which are about to be cinematographically demonstrated are not made sufficiently frequent to give a perfectly smooth appearance to the wave, and the fact that they are not well centered on this film gives a very vivacious appearance to the stomach, but it will serve to illustrate a motor phenomena of the stomach and the great scope of this method of examination.

Resumé.—In closing I wish to give credit to Kaestle, Rieder and Rosenthal for the excellent work which they have done along this line, but would call attention to the fact that even their wonderful set of plates does not correspond to their rigid but correct definition of Roentgencinematography. I would also call attention to the difference between wave, contraction and cycle and the progression of the contraction from its origin to its termination. The duration of a peristaltic cycle is about two or three seconds, and at least ten or twelve radiograms should be obtained of different phases of peristaltic cycles.

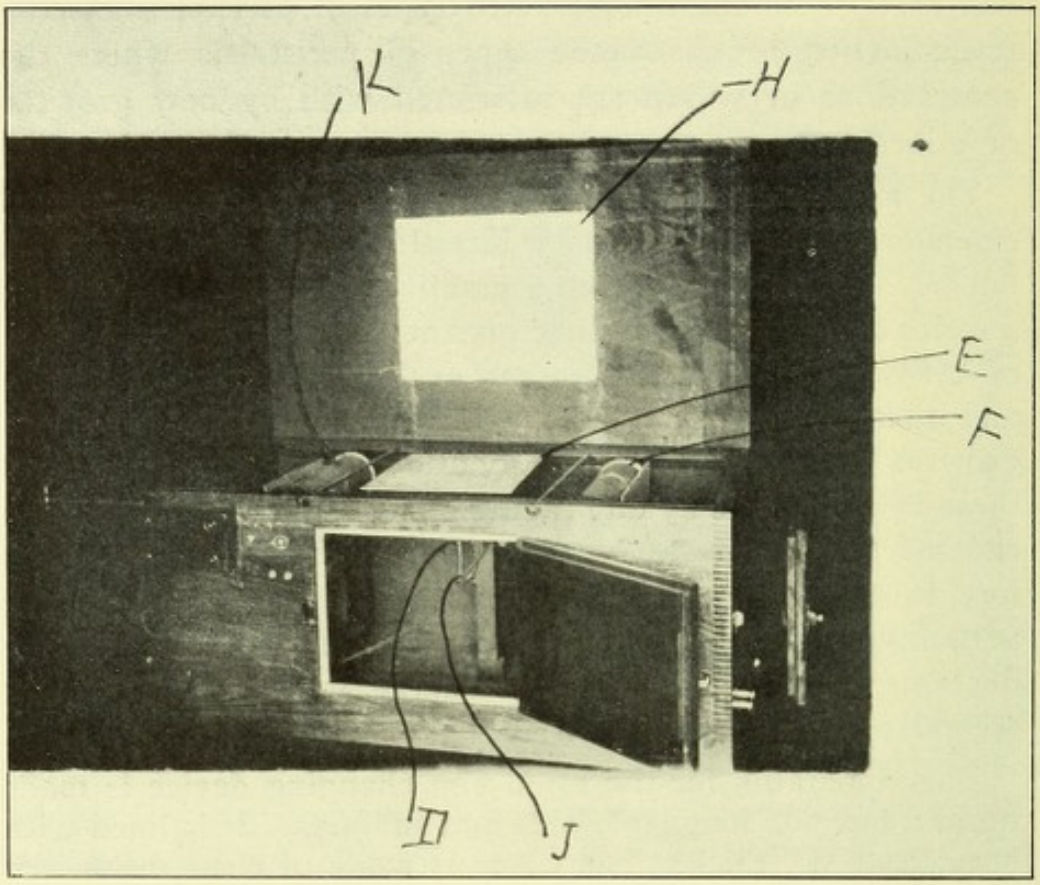
There are various types of peristaltic contractions which are best described as the one, two, three, and four-wave types of contraction with an intermediate type between the one and two-wave type which might readily be claimed either by Holzknecht or Kaestle, Rieder and Rosenthal, as representing the normal gastric phenomena. These types of peristalsis I

will refer to as the unobstructed types of peristalsis in contradistinction to obstructed types of peristalsis where the contractions or waves are interfered with by new growths or adhesions near the pylorus.

The author makes no claim that these are true Roentgencinematographs as defined by Kaestle, Rieder and Rosenthal, but he does claim that from a practical diagnostic standpoint, a series of eighteen or twenty instantaneous radiograms made of different phases of different cycles, studied individually and collectively, is of great value in the diagnosis of new growths and adhesions at the pyloric end of the stomach and these may be made by any radiographer without the use of an expensive yet imperfect plate, or film-changing device. Therefore, this work is within the reach of any radiologist, and the author will lay no claim to Roentgencinematographic reproductions until he succeeds in making four radiograms per second of gastric peristalsis.

This apparatus for the rapid film changing device is made up in a box 30″ long, 18″ wide and 12″ high. It is lined with sheet lead ⅛″ thick. The cover is made of clear soft white pine and is covered with lead except an open space 8x10 which is in the center of the cover. Directly under this in the center of the box is mounted a closed magnetic circuit type of electro-magnet "D," having an aluminum plate 1/16″ in thickness 8x10 and mounted on the plunger of the electro-magnet and on top of this aluminum plate is placed the intensifying screen "E." The electro-magnet is adjusted by "J" so that the plunger moves 1/16″ and when this movement takes place, the intensifying screen is brought up so that it presses firmly against the sensitive film above it. At each end are mounted two pasteboard tubes "F." On one of these is rolled the sensitive film. This is drawn across the intensifying screen and attached to the roll at the other end. The bearings of each of these rolls are mounted on an arrangement for adjusting the tension so that they turn rather hard. This is so that there will be no slack to the film when it is in operation.

On the end that has the roll that winds up the film "K" there is an arrangement with a ratchet (this is inside of the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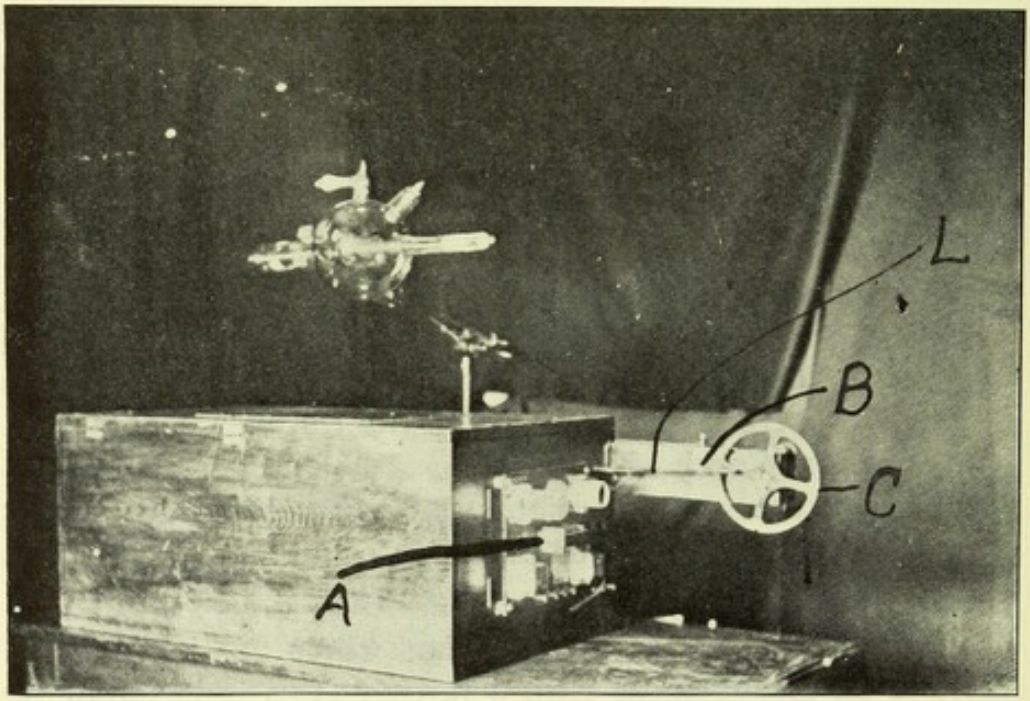
L
B
C
A

box and cannot be shown on photograph) so that as the handle of the device makes a half turn the pasteboard tube "K" makes a full turn which just winds up 8 inches of film.

On the other end of the apparatus there is an electro-magnet "A" having a silver contact mounted on the plunger and another silver contact mounted on an adjustable screw. This electro-magnet is placed in series with the electro-magnet "D" that throws the intensifying screen up against the sensitive film so that they both work at the same instant.

On the connecting rod "L" between the ratchet arrangement that winds up the film is placed a spring contact "B" which closes the current through both electro-magnets. The current from the primary of the X-Ray apparatus is closed when the two silver contacts operated by "A" come together.

Both electro-magnets are operated by the same set of storage batteries or dry cells.

The apparatus operates in the following manner:

The first half-turn of the crank winds the film. When the crank is turned three-quarters round, the spring contact "B" is closed which operates the electro-magnets "A" and "D," closing the current through the primary of the X-Ray apparatus, at the same instant pressing the intensifying screen firmly against the sensitive film above it. Then just before completing the revolution of the handle the battery circuit through the above electro-magnets is broken so that the current from the X-Ray apparatus is turned off and the intensifying screen drops back away from the sensitive film.

The above cycle of events takes place with every complete revolution of the handle which can be operated by hand or an electric motor. The apparatus, of course, has to be loaded in a dark room or the rolls well covered with black paper, similar to the regular film roll, used in an ordinary camera.