An Address

ON

INVESTIGATIONS OF THE MOTOR FUNCTIONS OF THE ALIMENTARY CANAL BY MEANS OF THE X RAYS.

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BY

ARTHUR F. HERTZ, M.A., M.D. OXON, F.R.C.P.,

ASSISTANT PHYSICIAN AND PHYSICIAN IN CHARGE OF THE
DEPARTMENT FOR NERVOUS DISEASES, GUY'S
HOSPITAL.

WHEN I received the honour of an invitation to address this Division, I thought that I could not do better than fall in with the suggestion of your Secretary that I should deal with the progress in our knowledge of the motor functions of the alimentary canal in health and disease which has resulted from the use of the *x* rays.

The Oesophagus.

In the act of swallowing the food can be seen to pass with great rapidity to the back of the pharynx and thence equally quickly down the oesophagus. When it reaches the cardiac orifice its rapid progress is arrested owing to the sudden diminution in lumen, with the result that it runs slowly into the stomach and its upper limit has time to become horizontal. The interval which elapses between the commencement of the deglutition act and the disappearance of the last traces of food from the oesophagus varies between four and nine seconds in different individuals, half of the total period being occupied in reaching the lower end of the oesophagus, the other half in the passage through the cardia.

Fig. 1.—Epithelioma of the extreme cardiac end of the oesophagus (1 in. below the diaphragm), showing accumulation of bismuth-containing food in the dilated oesophagus above the obstruction and peristaltic waves attempting to overcome the obstruction.

if other methods have failed to indicate the cause of the symptoms from which the patient suffers.

The Stomach.

Our knowledge of the anatomy and physiology of the stomach has been completely revolutionized as a result of investigation with the *x* rays. It is now known that the old conception of the stomach as a flaccid bag lying horizontally high up in the abdomen is completely wrong. The fundus, which lies beneath the left dome of the diaphragm and always contains gas, passes into the body of the stomach at the level of the cardiac orifice. In the vertical position the body is of nearly uniform width and is situated entirely to the left of the middle line. It is either vertical or inclines slightly towards the right, and is separated from the pyloric part of the stomach by the incisura angularis on the lesser curvature (Fig. 2). The pyloric part of the stomach consists of the pyloric vestibule, which is directed upwards as it passes to the right of the middle line, and the pyloric canal, which is about an inch in length, and passes backwards, upwards, and to the right, its termination projecting into the duodenum. As a result of the tonic contraction of the sphincter which surrounds the pyloric canal, the latter is

normally empty, even when the rest of the stomach is full.

In the vertical position the greater curvature almost invariably reaches below the umbilicus. In the horizontal position the greater curvature rises one or two inches, and comes to lie above the umbilicus (Fig. 3); at the same time

Fig. 2.—Normal stomach in the vertical position.

Fig. 3.—Normal stomach in the horizontal position.

o, End of oesophagus; F, fundus of the stomach containing gas; I A, incisura angularis; P C, pyloric canal; U, umbilicus.

the diaphragm ascends slightly, and the fundus rises with it. The lowest part of the stomach can be lifted between two and four inches by voluntary contraction of the abdominal muscles, and it can be caused to drop by their voluntary relaxation.

The stomach always contains gas, all of which collects in the fundus in the vertical position. After a meal the horizontal upper limit of the gastric contents can be clearly seen, most of the fundus being still full of gas; on shaking the body, the splashing of the fluid or semi-fluid gastric contents can be watched, and on leaning to one side the horizontal upper limit can be seen to be maintained. In the empty condition only the pear-shaped upper third of the stomach contains gas, the rest of the organ passing to the pylorus in the form of a collapsed tube, which corresponds in position to the lesser curvature of the full stomach.

From what has already been said it is clear that percussion of the stomach, whether empty or full, can only give information as to the area occupied by the gas it contains, and this bears no sort of proportion to the size of the organ. Although it is possible by means of auscultatory percussion to mark out a very definite area, which was formerly believed to be that occupied by the stomach, the *x* rays have proved that in reality it yields an even less accurate representation of the stomach than simple percussion.¹

Investigations with the *x* rays have also shown how impossible it is for anybody to interpret the meaning of his symptoms correctly. Thus I have seen numerous patients, including several medical men, in whom an *x* ray examination in the vertical position showed that no excess of gas was present, although they complained of a sense of fullness in the stomach, which they were convinced was due to flatulence, and which they were constantly endeavouring to relieve by eructation.²

Vertical.

Horizontal.

Fig. 4.—Ptosis of an otherwise normal stomach, disappearing in the horizontal position.

With the *x* rays any abnormality in the position and shape of the stomach can be readily observed. By no other means can gastropotosis be invariably diagnosed with certainty, for in many cases in which the stomach is quite normal in position when the patient lies down, as he does for ordinary abdominal examination, it drops to a remarkably low level as soon as he stands up (Fig. 4). I have

been much struck by the fact that severe gastropotosis is not uncommon in individuals whose abdominal muscles are well developed, and whose other viscera do not appear to drop excessively when the erect posture is assumed. Hour-glass stomachs can be readily recognized with the *x* rays, but it is important to remember that various conditions, some of which I shall allude to later, may produce a functional hour-glass constriction, which can

lowest part of the stomach sags so deeply and the body of the stomach becomes so stretched that the lumen of the latter is finally obliterated; if any more food is now swallowed it collects in the upper part of the stomach and does not pass to the dependent part at all, a condition being produced which I have called *orthostatic hour-glass stomach* (Fig. 9), as it disappears immediately the horizontal position is assumed.

Fig. 5.—Organic hour-glass stomach, due to cicatrization of a gastric ulcer.

Fig. 6.—Filling of the normal stomach. U, Umbilicus; L, upper limit of gastric contents.

generally be distinguished from the organic form by the fact that in the latter the neck does not pass from the most dependent part of the upper segment (Fig. 5). The presence of adhesions leading to fixation or deformity of some part of the stomach can be recognized with the *x* rays; but, unfortunately, they do not often give much assistance in the really early diagnosis of cancer.

The tone of the stomach can be very satisfactorily in-

When the tone of the stomach is excessive, its greater curvature does not reach the umbilicus in the vertical position and in extreme cases the organ lies very obliquely immediately below the liver. The most common cause of hypertonus is duodenal ulcer (Fig. 10); in a somewhat considerable experience I have invariably found a hypertonic stomach in this condition unless the ulcer had led to organic obstruction. This is of great practical importance,

Fig. 7.—Filling of the atonic stomach. U, Umbilicus; L, upper limit of gastric contents.

Fig. 8.—Pyloric obstruction due to duodenal ulcer; dilatation and hypertrophy of stomach.

vestigated by means of the *x* rays. Owing to its adaptation to the bulk of the gastric contents, there is very little difference in the upper limit of the latter, whether their volume be 40 or 400 c.cm., and the greater curvature is very little depressed as the stomach is gradually filled (Fig. 6). When atony is present, this adaptation no longer occurs, and the food drops into the most dependent part of the stomach, so that its upper limit may even be below the umbilicus instead of between 1 and 2 in. below the

as it assists in the differential diagnosis between duodenal and gastric ulcer, as hypertonus is rarely found in the latter condition. Moreover, when hypertonus is present in duodenal ulcer, the prospects of cure by medical means are generally good, whereas the slightest degree of dilatation indicates that a gastro-enterostomy is essential in order to overcome the obstruction. Hypertonus occurs in some cases of gall-bladder disease and of chronic appendicitis, and it may also result from a course of strict dieting in a

Fig. 9.—Orthostatic hour-glass stomach. A, Vertical position, first stage. B, Vertical position, second stage. C, Horizontal position.

Fig. 10.—Hypertonic stomach due to duodenal ulcer.

Diaphragm; as more food is taken, the greater curvature sinks more and more deeply and the upper level of the contents only rises to a comparatively small extent (Fig. 7). In the extreme degrees of dilatation, which occur in cases of long-standing pyloric obstruction, the dilatation may be so great that none of the food taken at an ordinary meal ever reaches the pyloric end of the stomach so long as the patient is in the erect position (Fig. 8). When ptosis is present in addition to atony, the

patient who has been kept in bed. Spasm near the centre of the stomach can occasionally be observed, particularly in cases of gastric ulcer; it gives rise to a condition of temporary hour-glass stomach (Fig. 11).

The activity of peristalsis can be readily determined with the *x* rays, and the complete independence of peristalsis and tone has only been recognized since this method of examination was introduced. Thus normal peristalsis is frequently observed in atonic and dilated stomachs, and

in rare cases peristalsis may be deficient in hypertonic stomachs. In organic pyloric obstruction increased peristalsis can often be observed before it is visible through the abdominal wall, and instead of commencing in the middle of the greater curvature it can be seen to start near the fundus and to produce a complete separation of the contents of the pyloric end from those of the rest of the stomach at a point considerably more distant from the pyloric canal than is normally the case. I have only once

Fig. 11.—Spasmodic hour-glass stomach with no ulceration. A, Spasm present. B, Spasm disappeared after vigorous contraction of abdominal muscles.

seen antiperistalsis in the stomach; when present it is a conclusive sign of organic obstruction.

The rate of evacuation of the stomach can be estimated with the *x* rays if care is taken that nothing is eaten or drunk until every trace of the shadow of the bismuth meal has disappeared. The *x* rays have shown that the stomach begins to empty itself immediately food enters it, and the evacuation continues without intermission until it is complete.

The Small Intestine.

Indications of the rapid passage of chyme through the small intestine can be observed with the *x* rays, and under favourable circumstances segmentation, which mixes the food with the intestinal juices and promotes absorption of the products of digestion without causing any forward movements of the intestinal contents as a whole, can be watched (Fig. 12). The bismuth-containing chyme is most concentrated in the duodenum before it has become mixed with the bile, pancreatic juice and succus entericus; the position of the duodenum can therefore frequently be determined. I have never observed true stasis in the duodenum, except in cases of organic obstruction, and to a less extent in extreme gastropnoxis, in which a kink may occur at the point where the duodenum becomes fixed. I am convinced that kinking of the duodenum plays no part whatever in the etiology of duodenal ulcer, as has recently been suggested, for nothing could be less likely to cause kinking than the hypertonic condition of the stomach present in duodenal ulcer; the latter is, indeed, invariably associated with an unusually rapid passage of the chyme into the more distal parts of the small intestine. The tonic contraction of the ileo-caecal sphincter leads to a slight delay at the end of the ileum, comparable to that which occurs at the lower

Fig. 12.—Diagram to illustrate the consecutive stages of segmentation in the human small intestine. Corresponding points are marked with the same letter.

end of the oesophagus. Consequently segmentation can be more easily observed in the last few inches of the ileum than in any other part of the small intestine. In a few cases I have seen a true kink near the end of the ileum, which has led to more or less obstruction, but in every instance this has been due to adhesions caused by an antecedent attack of appendicitis. I do not believe that a kink in the ileum is of any importance in the etiology of simple constipation, as a delay of more than a few hours

is never observed in the end of the ileum, and this is merely an exaggeration of the normal delay caused by the ileo-caecal sphincter.

The Colon.

Like the stomach, the colon undergoes considerable alterations in its situation according to whether the horizontal or the vertical position is assumed (Fig. 13).

Fig. 13.—Influence of posture on position of colon in a normal individual. A, Vertical position. B, Horizontal position.

The only fixed point is the splenic flexure, the hepatic flexure frequently dropping an inch or more when the individual stands up. The caecum varies greatly in position; it is not very rare to find it in the true pelvis in perfectly healthy individuals, who have never suffered

Fig. 14.—Post-dysenteric atony and paresis of the colon. Compare this lumen of the colon and the slow passage of faeces through it with Fig. 16.

Fig. 15.—Constipation with muco-membranous colitis, showing spasm of descending and iliac colon.

from constipation. Both the splenic and the hepatic flexures often appear to be extremely acute even in normal individuals; but the appearance with the *x* rays is somewhat deceptive, as the transverse colon is on a more anterior plane than the ascending and descending colon. By manipulation of the abdomen during a screen examination it should be possible to separate from each other the limbs of the hepatic flexure and of the splenic flexure; if this cannot be done, it may be assumed that the limbs are bound together by adhesions. Similarly, if it is impossible to move the shadow of the iliac colon by manipulating the left iliac fossa, it is probable that pericolicitis is present, and in some cases of chronic appendicitis the caecum is also found to be abnormally fixed.

The lumen of the transverse and descending colon is very much less than that of the caecum and ascending colon, but in atony, due to such conditions as chronic dysentery, the lumen of the whole colon may be uniformly enlarged (Fig. 14). On the other hand, in spastic constipation, which is associated with the passage of membranes in the condition known as muco-membranous colitis, various segments of the colon may be seen to be abnormally contracted (Fig. 15).

The rate of the passage of faeces through the large intestines can be estimated with the *x* rays. The caecum is normally reached in a

Fig. 16.—Diagram of normal large intestine, the pelvic colon being represented in the position it occupies when full. The numbers represent the hours after a bismuth breakfast at which the different parts of the colon are reached. C, Caecum; A.C., ascending colon; H.F., hepatic flexure; S.F., splenic flexure; D.C., descending colon; I.C., iliac colon; P.C., pelvic colon; R., rectum; U., umbilicus; P., pelvis.

little over four hours after the bismuth meal, the hepatic flexure two hours later, the splenic flexure three hours after the hepatic flexure, and the beginning of the pelvic colon twelve hours after the commencement of the meal (Fig. 16).

Fig. 17.—Diagram of the pelvi-rectal flexure, rectum, and anal canal. P.R.F., Pelvi-rectal flexure; V.H., lowest valve of Houston; R.A., rectal ampulla; L.A., levator ani; I.S.A., internal sphincter ani; E.S.A., external sphincter ani; F., faeces in pelvic colon.

tion is normal (Fig. 19). In *dyschezia*, on the other hand, the passage through the intestines as far as the pelvic colon is normal, but defaecation is inefficiently performed, and the rectum and pelvic colon are never properly emptied (Fig. 20).

Treatment.

The mode of action of different forms of treatment can often be studied by means of the *x* rays. Thus the stimulating influence of food, taken into the stomach on intestinal peristalsis can be recognized (Fig. 21), and the effect of a suitable diet in the treatment of intestinal constipation can be watched (Fig. 22). The *x* rays afford a very valuable means of investigating the pharmacology of aperients and other drugs which influence the motor functions of the alimentary canal; as this method of research is still in its infancy I shall not discuss it more fully at the present moment.⁴ The position of

Under normal conditions the faeces do not pass beyond the sharp pelvi-rectal flexure until immediately before defaecation, but accumulate from below upwards in the pelvic colon (Fig. 17). Investigations carried out with the *x* rays four years ago demonstrated that in defaecation active peristalsis of the whole of the colon occurs, and under normal conditions everything beyond the splenic flexure is evacuated (Fig. 18).

CONSTIPATION.

My *x* ray investigations have shown that it is possible to separate all cases of constipation into two main groups.³ In *intestinal constipation* a delay occurs in the passage through the colon, especially in its distal half, but defaecation

gives as to the place where massage can be most usefully applied.

Although the relief of the abdominal discomfort and circulatory symptoms of visceroptosis obtained by the use

Fig. 18.—Normal defaecation; showing active participation of the whole colon and complete evacuation of everything above the splenic flexure.

of a suitable abdominal support is very striking, it is interesting to observe with the *x* rays that the position of the dropped stomach and colon are often unaffected

Fig. 19.—Intestinal constipation: 24 hours after bismuth meal. Subsequent examinations showed that a similar delay occurred along the whole of the large intestine.

Fig. 20.—Dyschezia: 24 hours after bismuth breakfast. The patient felt no desire to defaecate.

(Fig. 23). Prolonged rest in bed with the foot of the bed raised has been shown by the *x* rays to result in a permanent improvement in the position of the stomach and colon in many cases of severe ptosis.

An *x*-ray examination is not infrequently useful for its mental effect on the patient, as it may remove the fear of cancer or obstruction which is so common in nervous individuals suffering from constipation. In some cases,

Fig. 21.—Hourly tracings to show effect of meals on the movements of the colon.

Fig. 22.—A, Non-stimulating diet, leading to constipation. B, After five days of stimulating diet (porridge, green vegetables, fruit, etc.).

the colon and the situation of delay in cases of intestinal constipation vary so greatly that an *x* ray examination is often of great value for the information it

moreover, it may help to dispel the fixed idea held by perfectly healthy people that unless they take an enormous quantity of aperients they will never get their bowels

open. Thus, having found by means of the x rays that a young man who had been in the habit of taking large doses of vegetable and saline purgatives every day was really not constipated at all when he was taking no medicine, I was able to persuade him on two consecutive mornings to open his bowels without artificial help, after demonstrating to him that the faeces had passed through his intestines, and were simply waiting in his rectum to be expelled.

The results of operation on the alimentary canal can be investigated with the x rays. My observations have convinced me that gastro-enterostomy is always a drainage operation, and that in successful cases most of the food leaves the stomach through the stoma whether pyloric obstruction is present or not. For this reason the anastomosis should always be made in the pyloric end of the stomach even if the ulcer is near the cardiac orifice. When the operation is unsuccessful it is generally due to the alteration which occurs in the relative position of the parts concerned when the vertical position is assumed; this is least marked with a hypertonic stomach, a fact which explains the rarity of vomiting and other unpleasant symptoms after the operation in cases of duodenal ulcer. I have now seen a number of patients on whom a gastro-enterostomy had been performed for various reasons, who, though cured of their original complaint, were much troubled during and immediately after meals by a feeling of fullness just above the umbilicus,

Fig. 23.—Failure of abdominal support to keep transverse colon, which had dropped into the true pelvis, in normal position in the erect posture.

Fig. 24.—Five years after gastro-enterostomy for small duodenal ulcer which did not produce obstruction.

and who in some cases also suffered from diarrhoea after taking food. In these cases the food runs with such rapidity out of the stomach into the jejunum that none accumulates in the former, but the latter is over-distended; this overdistension is doubtless the cause of the discomfort (Fig. 24). Relief is obtained if the patient eats with extreme slowness, especially if the ordinary meals are replaced by smaller and more frequent ones; at the same time the diarrhoea can generally be controlled by the administration of a preparation of pancreatic ferments, which helps digestion in the intestine to compensate for the absence of digestion in the stomach, and also to a certain extent makes good the deficiency of pancreatic juice which results from the absence of the normal stimuli to its secretion.

I have covered such an extensive field in these remarks that I have only been able to give some slight indication of the most important results which have followed the employment of the x rays as a method of investigating the physiology and pathology of the alimentary canal. But I hope I have succeeded in awakening your interest in this fascinating subject, and showing you what great advances have already been made in our knowledge in the five years which have elapsed since Rieder showed that it was possible to apply the methods previously used by Cannon on cats to human physiology and pathology.

REFERENCES.

¹ BRITISH MEDICAL JOURNAL, March 14th, 1911. ² Goulstonian Lectures on Sensibility of the Alimentary Canal in Health and Disease, Oxford, 1911. ³ Constipation and Allied Intestinal Disorders, Oxford, 1909. ⁴ Guy's Hospital Reports, lxiii, 297, 1909.

THE authorities of the United States navy have followed the example of the army by making antityphoid inoculation compulsory in the case of all officers and enlisted men under the age of 45. Henceforward all recruits enlisted will have to submit to vaccination against typhoid fever as they now do against small-pox.

THE IMPORTANCE OF PELVIC DEPOSITS IN THE DIAGNOSIS OF ABDOMINAL CANCER.

BY

G. GREY TURNER, M.S.DURH., F.R.C.S.ENG.,

HONORARY ASSISTANT SURGEON, ROYAL VICTORIA INFIRMARY, NEWCASTLE-UPON-TYNE.

In a certain proportion of cases of carcinoma in the upper abdomen, portions of the growth find their way into the general peritoneal cavity, and then into the pelvis, where they become implanted and grow, in many cases giving rise to a mass easily palpable per rectum. Whether the particles simply gravitate to the pelvis, or arrive there as the result of the natural drainage of peritoneal fluid assisted by intestinal movements, or are carried in some other way, is of no moment for my present purpose.

The masses are to be felt in the recto-vesical pouch or pouch of Douglas, on the anterior wall of the bowel,

within three or four inches of the anus. They may be single or multiple, and are either detected as a definite fixed nodule or nodules or as an infiltration. As a rule they feel about the size of a small hazel nut, though they may be much larger. In my cases the presence of the deposits has not given rise to any symptoms whatever, and they have only been discovered in the course of routine examination. Cases, however, have been recorded¹ in which the growth apparently originated in the rectum. Should this question arise, the matter could readily be cleared up by sigmoidoscopic examination. In cases of malignant disease in the upper abdomen, and especially with stomach cancer, while there may be no signs of dissemination to be made out on ordinary abdominal examination and no ascites, there may be quite a considerable deposit in the pelvis, easily recognizable on rectal examination and without any symptoms to point to its presence.

The first case which came before my notice was mentioned by me in an address delivered before a meeting of the British Medical Association at Sunderland² on April 3rd, 1906, as follows:

The Importance of Rectal Examination.

In my hospital work nothing has struck me more than the neglect of this method, for seldom a month passes without my seeing cases of serious rectal mischief that have been overlooked or wrongly interpreted for the want of proper local examination. It is indispensable in a complete examination of the peritoneal cavity, for it is only by this route in the male that the recto-vesical pouch can be properly explored. I am familiar with no better instance of its value in this connexion than the circumstances of the following case.

Fig. 1.—Represents diagrammatically a vertical section of the peritoneal cavity. The arrows show the directions in which a stomach growth may spread. The mass in the recto-vesical pouch is a peritoneal deposit of growth.