One more practical point, which I have found of great use, is the finding of the obstruction. Much needless exposure, and therefore much avoidable shock, is prevented by first examining the caecum and terminal ileum. Distension of the caecum, of course, means obstruction in the large intestine, and the condition can be dealt with as below. But if one finds a piece of collapsed ileum, this should be followed towards the stomach until the distended intestine is met. The examined part is returned as finished with. This method only requires about 2 in. of gut to be out of the abdomen at any one moment.

It should always be kept in mind that there may be more than one band causing obstruction; in my series there were two such cases.

In this series there were 46 cases which required resection; 11 of these were intussusceptions, with 9 deaths. This is in marked contrast with the reducible cases, of which there were 15 with 1 death. The youngest successful resection was in a girl just under 3 months old.⁵ The mortality of all resections was 45.4 per cent.

Of the cases in Group 2, 12 were the result of bands and adhesions due to the presence of tuberculous mesenteric glands, 9 to bands not of tuberculous origin, 4 to Meckel's diverticulum acting as a band, 1 to the appendix acting as a band, and 13 to adhesions resulting from previous operations—2 of these occurred during the first few days after appendicectomy with drainage. It is interesting to note that when adhesions caused the obstruction, this appeared to result from a rotatory effect given to the intestine rather than from kinking.

The volvulus cases were both of the caecum—one was merely reduced and fixed, the other required resection.

The internal hernia was through a hole in the mesentery, and whether of congenital origin or not was not determined, though there was no history of injury.

The case of thrombosis of the mesenteric vessels required resection of some 4½ feet of small intestine, apparently about the lower jejunum, and was successfully accomplished.

In the gall-stone case the stone was impacted in the lower ileum, and was removed, the intestine being sutured.

Of the external hernia cases there were 170, with 18 deaths, a mortality of 10.5 per cent. Fifty were inguinal, with the strangulation at the external abdominal ring in at least 40—it was only found at the internal ring in 5; there were 3 deaths. Ninety-eight were femoral, with 11 deaths. Eighteen were umbilical, with 4 deaths.

Resection was performed only once in the inguinal cases, 18 times in the femoral, and 4 times in the umbilical.

It is interesting to note how much more serious to the vitality of the intestine is a femoral hernia, probably due to the much tighter ring.

Most of the femoral hernia cases were operated on from the abdomen through the outer part of the rectus sheath. It was necessary to free the sac from below, and Gimbernat's ligament was also usually divided from below. The peritoneum was efficiently protected, and first the gut reduced and dealt with from above, and later the sac was turned inside out into the abdominal wound. There is a distinct advantage in this method in two ways—first, it gives much more satisfactory access in case resection be necessary, and secondly, a radical cure is more easily effected, for the neck of the sac can be stitched up into the abdominal wound and the inner end of Poupart's ligament can be stitched to Cooper's ligament under direct observation on the upper side of the pubic arch. Also, if thought necessary, a piece of the rectus muscle can be carried across to Cooper's ligament, though I have never found that this was required. I have never seen a case recur after this method, though it is probably claiming too much for it to expect never to see a recurrence.

As regards the carcinomata cases, it usually happens that a positive diagnosis is only made after an exploration by a right para-umbilical incision. It is unfortunately true that most cases of carcinoma of the colon are only recognized either after giving rise to acute obstruction or on the discovery of a tumour. When the patient is desperately ill it is better to do typhlotomy at once, but when possible an exploration is advisable to ascertain the position of the growth and the feasibility of subsequent removal. If the growth is in the sigmoid and irremovable a colostomy should be done, but if removable, typhlotomy.

There is no doubt that the danger of sepsis at the second operation is thereby much reduced. A growth higher up in the colon requires either typhlotomy or, when in the descending colon or left half of the transverse colon, transverse colostomy may be done; if, however, there is a removable growth in these parts I believe it is always better to do typhlotomy.

Carcinoma of the rectum, of course, can be diagnosed before operation, and in any case requires a colostomy.

REFERENCES.

¹ Wilkie, *Experimental Observations on the Causes of Death in Acute Intestinal Obstruction*. ² McLean and Andries, *Journ. Amer. Med. Assoc.*, November 2nd, 1912. ³ Dale and Laidlaw, *BRITISH MEDICAL JOURNAL*, March 24th, 1917. ⁴ Crile, *Assoc.-association: Crile and Lower*. ⁵ Flint, *Lancet*, May 31st, 1913.

ABDOMINAL PAIN:

ITS MECHANISM AND CLINICAL SIGNIFICANCE.*

BY

A. E. MAYLARD, B.S.LOND., F.R.F.P.S.GLASG.,
F.R.S.EDIN.,

HONORARY CONSULTING SURGEON TO THE VICTORIA INFIRMARY,
GLASGOW.

POSSIBLY no symptom in the whole realm of disease is of greater interest and of wider distribution than that of pain. To the uninitiated it is often considered a mystery, more perhaps from its moral aspect than from its clinical. To those of us who regard it in the light of an indication that Nature is conveying information of considerable physiological and clinical importance in the elucidation of functional and pathological disorders, it becomes a subject of the greatest significance. As a study in itself, pain embraces an accurate knowledge of certain anatomical and physiological facts, as well as a comprehensive investigation into the morbid processes of disease. The subject is naturally a very wide one, and in the short hour at my disposal I can only deal with it in a very restricted way. My remarks, therefore, are to be limited to the discussion of pain as it is manifested in the abdomen.

For us, as clinicians dealing with the symptoms of disease, the most practical part of all these considerations about the nerve supply of the various parts of the body is that which concerns the ultimate distribution of the spinal nerves; for it is by means of these that we gain a great deal of our clinical information regarding the various seats of disease, and sometimes also the particular nature of the disease. It behoves us, therefore, to remember very accurately the final distribution of every nerve that leaves the brain and spinal cord to end in some part of the body. Take, as an example, the sixth thoracic intercostal nerve. In its course between the sixth and seventh ribs it gives off close to the spine its posterior primary branch, which is distributed to the skin between the lower angles of the scapulae; then, about the middle of the intercostal space, from before backwards, it gives off its lateral cutaneous branch, which ends in the skin on the side of the chest a little below the level of the lower end of the scapula; and, finally, the nerve ends in the sensory organs contained within the skin of the epigastric region at its upper part.

[Here the lecturer showed by means of diagrams the various anatomical connexions between the sympathetic nerve system, the spinal cord, the nerves, and the viscera.]

Clinical Significance of Pain.

Let us turn our attention to the practical application of the knowledge by which communications take place between the brain and spinal cord and the various parts of the body, and see how it works out in the diagnosis and treatment of disease. As a first clinical example we may take pain felt in the epigastrium, the side, and the inter-scapular region in the case of chronic gastric ulcer. The nerve supply of the stomach is, of course, by means of the two vagi and the sympathetic solar plexus, the latter being intimately connected with the coeliac plexus, which in its turn receives nerve branches from the subsidiary plexuses that are directly associated with the stomach. When, then, ulcer of the stomach causes pain to be felt in

* Abstract of a lecture delivered to the students of Queen Margaret College, University of Glasgow.

the parts before mentioned, the lines of communication between the seat of disease and the centres of pain are those that have already been anatomically traced; thus, from the great solar plexus, the large splanchnic nerves pass upwards to the sixth thoracic sympathetic ganglia, fibres from which pass onwards to the cells in the posterior cornua of that segment of the cord which also receives fibres from the sixth thoracic intercostal nerve. Now, inasmuch as these spinal nerves have at their terminals sensory organs capable of producing the impression of pain it follows that this pain will be experienced in those parts where these sensitive organs are located; and those in the case of the sixth intercostal nerve will be in the epigastrium, the side of the chest, and between the shoulder blades. Pain thus occurring not at the actual seat of disease, but at some other place, often at a considerable distance, is called a "referred" pain. Nearly all pains felt in connexion with abdominal disease connected with the viscera are of this "referred" character.

To illustrate this further, let us take some other examples: those, for instance, connected with the presence of gall stones and those associated with the existence of calculi in the kidney. Here we have two organs closely related anatomically to each other, with many symptoms also much alike, but in which the acute colicky pains are widely different in their seats of distribution. To explain this divergence of two organs so closely related and so similarly affected, we have simply to refer to the anatomical distribution of the nerves respectively associated with each viscus in order to ascertain how the affected viscera cause the symptom to become manifested in a distant part of the body. In the case of gall stones, the first link in the chain is the hepatic sympathetic plexus. This plexus is, of course, connected with the coeliac plexus, itself intimately associated on the one side with the great solar plexus, and on the other side with the phrenic ganglion, which is situated in the diaphragm. It has already been shown in the case of the stomach how the solar plexus by its somatic connexions causes pain to be felt in the epigastrium. It is the connexion of the hepatic plexus with the phrenic ganglion situated in the diaphragm that explains the right shoulder pain; for this ganglion, through the medium of the phrenic nerve, is brought into relation with the fourth cervical nerve that distributes branches over the shoulder.

Another interesting example of "referred" pain is that connected with acute appendicitis. In this disease the initial seizure is frequently felt in the umbilical region before the pain settles down into the right inguinal region. The sequence of events is not difficult to follow. The inferior mesenteric plexus supplies the ileo-caecal section of the intestinal canal, and therefore the appendix also; but this plexus, through the medium of the aortic plexus, connects with the solar plexus, so that a communication is set up with the large splanchnic nerve. This nerve connects, through the corresponding sympathetic ganglia, with the fifth to the ninth or tenth thoracic intercostal nerves, whose final distribution is the epigastric and umbilical regions, where are the sensory end-organs that give rise to the feeling of pain. That pain is later felt directly in the right iliac region over the actual seat of disease is probably due to the inflammatory involvement of the parietal peritoneum, which is an extremely sensitive structure, and readily causes pain when overstimulated by any unnatural agency.

I am anxious now to present the picture in another form. In our practical clinical work we do not begin with a knowledge of the organ diseased and explain the presence of the pain; we do just the reverse. We investigate the nature and situation of the pain, and from these data seek to discover the disease. I am going, therefore, to ask you to examine a specific instance of a patient suffering from pain, say, in the epigastric region, and to seek with me to differentiate its clinical significance. It should be remembered, in the first place, that we are dealing with a "referred" pain, not with pain that is dependent on some local mischief in the abdominal parietes, but with that which is the result of influences transferred from some distant organ or tissue. Our first natural thought connected with pain in this region would be that it might be of gastric origin, but as there may exist no other symptoms suggestive of disease or functional derangement of the stomach, what other causes could give rise to it? I think that if you have followed

me in all that I have already indicated regarding the way in which the various nerve influences are conveyed you will readily understand how it is possible for certain sensitive cutaneous areas to be the focalizing seats of pain indicative of disease in more than one organ or tissue. This fact is very plainly demonstrated in the case of epigastric pain. You will remember how many abdominal viscera are associated through the medium of their respective sympathetic plexuses with the great central solar plexus, and how this plexus again, by means of the large splanchnics, is brought into connexion with the sixth and other intercostal nerves; so that, for instance, any acute disease of the pancreas—to mention only one viscus—would be as likely to cause pain in this region as an acute gastric disturbance.

What I wish more particularly to draw your attention to is the fact that not only can epigastric pain result from influences derived from diseased viscera, but that the involvement of any link in the chain between its two terminals—the cutaneous structures and the viscera—can equally evoke pain in this region. Before the splanchnic afferent nerves can excite the somatic afferent nerves both must more or less come into association with the cells of the posterior cornua. If, then, these cells become unduly excited by disease in the spinal cord, which directly involves them, a precisely similar result ensues as if they had been overstimulated by influences brought to them by the splanchnic nerves. This is what happens in patients suffering from *tabes dorsalis*, who frequently complain of acute seizures—crises—of epigastric pain. But, further, suppose the sixth intercostal nerve is involved in any part of its course between the spinal cord and its ultimate seats of distribution, pain will similarly occur in the epigastric region. This is precisely what happens in some cases of pleuropneumonia and in tuberculous caries of the spinal column. It is extraordinary how many mistakes have been made where epigastric pain has arisen from these causes. In the early stages of our abdominal work I fear that there were few surgeons who would not have had to confess to errors of judgement in this respect, more particularly in the cases of inflammation of the lungs and pleura.

I might take up other cutaneous areas where "referred" pain is felt, the cause for which could be attributed to more than one source. I think, however, that I have said enough to excite your interest, and indicate to you the important clinical fact that we must never stake our diagnosis on one solitary symptom however prominent and significant that symptom may be. Possibly you will be struck more forcibly with the value of adopting this method of clinical research in seeking to trace the cause of a "referred" pain if I instance a somewhat puzzling case that I recently encountered. It was a patient who had acute appendicitis, and in whom the most dominating symptom was a severe and continuous pain over the right shoulder. It led to the natural inference that the cause of the trouble might be gall stones. But the deciding factor in arriving at a correct diagnosis was the rigidity of the muscles in the right iliac and lumbar regions, and the pain produced on deep pressure in these parts. The abdomen was therefore opened as for appendicitis in the right iliac region. The diseased viscus was found lying upwards under the ascending colon. It was free, but from the existence of free turbid fluid in and around the region of the appendix there was evidently a certain amount of peritonitis. This I think is the probable explanation of the "referred" pain felt in the shoulder. The peritonitis in the region of the appendix extended to the liver and the under surface of the diaphragm; this caused an involvement of the phrenic ganglion, and as the phrenic nerve connects this ganglion with the fourth cervical spinal nerve, the pain over the shoulder is at once explained. The fact that the removal of the appendix and the subsidence of the peritonitis completely cured the pain sufficiently suggests that the explanation given was probably the correct one.

Variations in Manifestation.

It is interesting to consider the various conditions that affect both the nature of the pain produced, its extent, and its degree of severity. As clinical factors of diagnostic significance they are of considerable importance. As regards the nature of pain, we are almost entirely at a loss to explain why, for instance, a pain should be of a

"burning" character, "cutting," "stabbing," or "gnawing" like toothache. A pain of the intermittent "colicky" or "gripping" type does, however, admit of a more or less satisfactory explanation, for it indicates an unduly violent effort on the part of involuntary muscles to expel some foreign or excessively irritative material, or to overcome obstruction. We encounter this type of pain in chronic intestinal obstruction, and also in the presence of renal and biliary calculi. With this exception, however, the other characters of pain seem to be inexplicable; and from the fact that the same disease may cause different types of pain we are unable—at least at present—to attach much clinical importance to these varied manifestations.

When we come to consider pain from the point of view of degree or severity we are brought up against some very interesting problems. The first of these concerns the individual regarded as a collective organism. Some patients have a much more sensitive nervous system than others, so that what may be easily endured by one may be almost beyond toleration by another. These normal constitutional variations are always worthy of careful consideration. Then we have the effect of certain blood conditions which may have an augmentative action on the sensitiveness of the system to pain. In fever, for instance, the increased temperature may unduly excite those cells in the spinal cord or brain which are concerned in the production of pain; and these cells may also be similarly affected in certain anaemic conditions of the blood—possibly, from impoverishment, the result of deficient or defective nourishment, they are more susceptible to stimulation.

With regard to the distribution of pain, there are equally some very interesting problems to solve. To give an instance or two of what I particularly refer to: Why should pain in appendicitis sometimes be felt in the left iliac region? Why should stone in the kidney on one side give rise to pain on the other—a reno-renal reflex as it is termed? You will remember that, when discussing the causes of "referred" pain, I indicated how it was in all likelihood explained: that certain cells in the posterior cornua of the spinal cord, lying in close contact with other cells, when stimulated, transferred that stimulation to those other cells, and thereby caused an impression to be produced which accounted for the particular location of the pain. Now, these cells in the one cornua are connected by nerve filaments with similar cells in the other cornua; and if we assume that, for some unexplained reason, the cells in the opposite cornua are more sensitive to exciting influences than those on the side of the disease, we get the impression produced that the disease is on that particular side.

Let me instance a case that came under my observation many years ago—in the pre-x-ray days. The misfortune which followed the operation performed could not very well happen now when, by means of photography, we are so able to assure ourselves as to the existence or not of a stone. The patient referred to complained of pain in the right lumbar region, strongly suggestive of renal calculus. The kidney was cut down upon and explored, but no stone was found. The patient died four days after the operation from suppression of urine, and at the necropsy a stone was found in the left kidney.

It is but a further extension of the explanation that I have just given to understand how it is that pain may be widely diffused or distributed and not "referred" to any particular part or region. For if owing to undue excitability of all the cells in the spinal cornua more than those normally stimulated become involved, you can readily appreciate how much more extensively diffused must be the area of pain felt. Thus it sometimes happens that when these cells are in an unduly excitable condition, or when, perchance, the stimulus itself is of so acute a nature that it oversteps the limitations of even normal cells, the pain resulting from disease of an abdominal organ may not be limited to any particular part of the epigastric, umbilical, or hypogastric regions, but be more or less diffused over two or more of these regions.

I have not time to touch upon many other points which the study of abdominal pain presents, and this short hour has only permitted me to deal with the fringe of my subject. If I have done no more than to excite your interest I feel sure that that awakened interest will prove useful to you in the future pursuit of your profession.

THE PHYSIOLOGICAL COST OF MUSCULAR WORK.

BY

LEONARD HILL, M.B., F.R.S.,

AND

J. A. C. CAMPBELL.

In the article published in this JOURNAL (May 7th, 1921, page 669) Waller and De Decker record results giving the physiological cost of muscular work of colliers, shoemakers and others as measured by the exhalation of CO₂. We are carrying out experiments of a similar nature with Dr. E. Schuster's modification of Martin's bicycle ergometer—doing 13,000 kg.m. of work per hour—using both the method employed by the above observers and the standard Douglas bag method, in which both the CO₂ output and oxygen use are measured, and the heat loss calculated therefrom, as recommended by Cathcart.¹ As the results we have obtained with these two methods rarely agree, we consider that the possibility of limitation of Waller and De Decker's method should be emphasized before deductions other than the broad difference between light and heavy work are drawn from their results. We consider that a source of error is the short duration—thirty seconds—of the period for obtaining the sample of expired air. We have found that the volume of CO₂ expired while at rest or at work varies greatly during consecutive half-minute periods (Table I), and also that the CO₂ exhalation per second obtained in a thirty-second sample is rarely similar to that obtained per second during a four-minute period (Table II).

TABLE I.—Consecutive Half-minute Samples of Expired Air.
(Subject J.A.C., unaccustomed to use of mouthpiece.)

Date.	Resting.			After working 1 hour on ergometer.		
	Sample.	Heat Loss.*	CO ₂ (c.cm. per sec.).	Sample.	Heat Loss.	CO ₂ (c.cm. per sec.).
April 1, 1921	1st	0.49	1.3	1st	4.76	15.7
	2nd	0.76	2.1	2nd	4.25	13.7
	3rd	1.10	4.1	3rd	4.00	12.6
April 4, 1921	1st	1.50	3.8	1st	4.49	13.1
	2nd	1.45	3.7	2nd	4.52	13.6
	3rd	1.24	3.3	3rd	4.00	13.8

* The heat loss in all tables is in terms of millicalories per square centimetre per second. Cathcart's method for calculation being used.
On April 4th J. A. C. had become more accustomed to the use of the mouthpiece.

TABLE II.—Half-minute and Four-minute Samples.
(No food taken. Subject C.P., accustomed to use of mouthpiece.)

Date		Half-minute Sample.		Four-minute Sample.	
		Heat Loss.	CO ₂ (c.cm. per sec.).	Heat Loss.	CO ₂ (c.cm. per sec.).
April 25, 1921	After 2 hours' work on ergometer	5.8	17.7	4.6	12.7
	After 3 hours' work on ergometer	6.3	19.2	—	11.0
	After 4 hours' work on ergometer	5.4	16.4	4.2	11.2
May 4, 1921	After 2 hours' work on ergometer	3.3	8.3	5.1	13.6
	After 4 hours' work on ergometer	4.8	12.7	4.9	13.2

Another factor on which these observers do not apparently place sufficient emphasis is the influence of food. Benedict and Carpenter have shown that the ingestion of all kinds of food in any amount results in an increment of metabolism.² We have obtained similar results. We think that there is a danger of a reader misinterpreting the charts and tables as presented by Waller and De Decker. In nearly all their cases the cost per hour of "practically maximal and constant" work appears to increase as the day proceeds. Johansson's curves of diurnal temperature