patients by the open-ended tube method reflects more the narrowed segment from which recording is made rather than any absolute increase in wall activity. It is possible that the exaggerated activity recorded by Painter and Truelove (1964) in patients with diverticular disease stimulated by morphia or prostigmine could be explained on the same basis. The higher intraluminal pressures occurring in the diverticular patients may contribute to the production of pulsion diverticula but the present findings would indicate that these pressures develop in a previously narrowed segment of bowel. Whether this narrowing exists before the diverticula appear cannot be determined on the evidence of this study. However, many cases are on record of diverticular disease with narrowing but no diverticula (Morson, 1963; Parks, 1966; Williams, 1967) so it seems possible that the muscular contracture is the primary lesion.

SUMMARY

The overall activity recorded using miniature balloons was similar in diverticular disease and in health under basal conditions and after the physiological stimulus of eating. The duration of activity was less but the amplitude of the waves was greater in diseased subjects.

Open-ended tubes detected more basal and post-prandial activity in diverticular disease than normal, but this does not necessarily indicate true muscular hyperactivity.

Intraluminal pressures are determined not only by wall movements, but the ease with which pressure segments are formed, and this implicates factors such as the diameter of the lumen, mucosal exuberance, and the nature of the bowel content.

REFERENCES


Part II Effect of colonic and rectal distension

The muscle of the sigmoid in diverticular disease is frequently thickened and rigid (Morson, 1963). It seemed likely, therefore, that its response to a stretching force might differ from normal. The resistance of colonic muscle to a stretching force has been little studied and the present work compares the response to stretch of muscle in diverticular disease and controls.

METHODS

Large balloons made from soft rubber with their centres 7.5 cm apart were connected via polythene tubing to both a water manometer and a multichannel electromanometer (Schwartz-München). A side arm into the system allowed the introduction of fluid. Three polythene tubes of 2 mm internal diameter with their tips 7.5 cm apart were used to assess intraluminal pressure changes (Fig. 1).

Studies were attempted on 28 patients with diverticular disease and 15 control subjects with first degree haemorrhoids. Where possible, the recording tips of the open-ended tubes were placed at 25, 17.5, and 10 cm from the anus, but in 12 cases of diverticular disease and in three controls it was not possible to pass the tubes beyond the rectosigmoid junction. In these cases only the effects of rectal distension could be observed. Thus
the sigmoid was distended in 16 and the rectum in 22 patients with diverticular disease. Colonic distension was performed on 12 and rectal distension on 13 of the control subjects.

When the colon was being distended, water at body temperature was introduced via the side arm in 20 ml increments, using a graduated syringe. A five-minute period was allowed to elapse before each increment was added. If the patient had abdominal discomfort, or an urgent desire to defaecate, the volume reached was noted and the fluid aspirated from the balloon. Where no such sensation occurred, up to 200 ml was introduced. The colonic balloon was emptied before rectal distension was started.

The mean tension within the balloon could be assessed by noting the height of the column of water in the side arm or from the tracing obtained on the electromanometer. When the side arm was closed off, pressure variation due to periodic contraction of the intestinal wall could be recorded.

The pressure recorded from the balloon was the sum of two factors: (1) the pressure due to the elasticity of balloon wall which was measured for each balloon used at different distending volumes and subtracted from each recorded pressure; (2) the pressure transmitted to the balloon by the intestinal wall.

The upper rectum was distended in a similar fashion, except that 40 ml increments were introduced. Intraluminal pressure changes above and below each balloon were observed and the area under the curve was taken as the index of total activity.

RESULTS

COMPARISON OF EFFECT OF DISTENSION ON THE DEFAECATION REFLEX IN DIVERTICULAR DISEASE AND IN CONTROLS Distension of the colon caused the desire to defaecate with a different distending volume in different individuals. With some, the sensation was present when 60 ml was introduced. With others, no such sensation was felt when volumes up to 200 ml were used. The desire to defaecate was precipitated with volumes of less than 200 ml in two-thirds of the control subjects during colonic distension and in half of them during rectal distension.

In both groups, there were a number of patients in whom experiments had to be terminated after only small volumes of fluid had been introduced into the distending balloons because of the desire to defaecate. The percentage of patients remaining in each group when the various distending volumes were being used is shown in Figure 2. The 'fall out' rate was higher in the diseased group due to the greater tendency to develop uncomfortable sensations.

EFFECT OF DISTENSION ON INTRALUMINAL PRESSURES The response to distension varied considerably in different individuals. In general, there was a marked increase in activity as recorded by open-ended tubes in the lumen of the bowel immediately above and below the distending balloon. When the sigmoid was being distended, there was little change in the motility of the rectum. Likewise, when the upper rectum was being distended, this had little influence on the colonic motility at the recording point 25 cm from the anus.

The volume of fluid required in the distending balloon to effect changes in intraluminal pressure varied widely from patient to patient. In many cases, the first increment of 20 ml caused a considerable increase in the motility. In other cases 60, 80, or 100 ml was introduced before any change was noted. In a few cases there was virtually no effect when up to 200 ml was used to distend the rectum.

With distension of the bowel, contractions occurred more frequently than when resting patterns were being recorded. The strength of the contraction was greater and was maintained for a longer time. The strength and frequency of the waves did not necessarily increase with the increasing degree of distension. In some cases, there was a falling-off both of the incidence and strength of contractions where large distending volumes were used. This inhibition occurred in the absence of any sensation of abdominal discomfort.

EFFECT OF DISTENSION ON WAVE FORM In both groups of patients the waves were always positive, even on the recording channel immediately below the distending balloon. There was no evidence of relaxation distal to the balloon associated with contraction proximal to the balloon.

The waves were usually simple in form, lasting up to 60 sec, indicating that the contractions were more
FIG. 3. Graphs of typical responses to stretch of normal colonic muscle.

FIG. 4. Graphs of typical responses to stretch of colonic muscle in diverticular disease.
sustained than normal. They seldom exceeded 30 cm H₂O in height.

In addition to the principal waves, continence waves were frequently recorded in response to distension. They were most common at rectal level and they occurred more frequently in diverticular patients than in normal controls.

During distension of the colon and rectum, fast wave patterns were seen only on a few occasions.

**VOLUME PRESSURE RELATIONSHIPS DURING COLONIC DISTENSION**

Graphs of the typical responses of colonic musculature to stretch are given for four control subjects (Fig. 3) and four patients with diverticular disease (Fig. 4). In the control subjects, the tension in the colonic wall tended to be higher and increase more rapidly with distension than in the diseased patients. In these patients, as the volume was increased, the muscle of the colon did not respond by increasing resistance. In some of the patients with colonic diverticula there was first a rise and then a fall in colonic wall tension with increasing distending volumes.

In 11 patients with diverticular disease and 11 controls it was possible to introduce distending volumes of up to 120 ml without discomfort. In the diverticular patients the tension developed in response to each distending volume was lower than in the control subjects. In the control group the average pressure rose steadily with increasing distending volumes, but in the diverticular group the mean pressure rose only from 20-2 cm H₂O with 20 ml distension to 25-0 cm H₂O when 40 ml was used, with no further overall increase with increasing volume. The difference in the response of the two groups became more marked with each increment (Table I). At both 100 and 120 ml levels the differences were statistically significant (0.02 > P > 0.01).

<table>
<thead>
<tr>
<th>TABLE I</th>
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<tbody>
<tr>
<td><strong>PRESSURE TRANSMITTED TO BALLOON BY SIGMID COLON IN RESPONSE TO STRETCH</strong></td>
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<tr>
<td>Distending Volume (ml)</td>
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**COMPARISON OF THE VOLUME PRESSURE RELATIONSHIPS DURING RECTAL DISTENSION**

Table II sets out the tension developed by the wall of the rectum in response to stretch in 10 controls and 14 patients with diverticular disease in whom volumes of 160 ml or more were used to distend the upper rectum. There was no difference between the control subjects and the patients with diverticular disease of the colon at any of the stimulating volumes. In both groups there was a progressive rise in tone with the addition of each increment.

<table>
<thead>
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<th>TABLE II</th>
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<tr>
<td><strong>PRESSURE TRANSMITTED TO THE BALLOON BY THE RECTUM IN RESPONSE TO STRETCH</strong></td>
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<td>Distending Volume (ml)</td>
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**DISCUSSION**

The most striking feature of the present study is that the tension developed in the bowel wall in response to distension is less in the diverticular segment than in the normal subject. The resistance of the diverticular muscle against a stretching force appears to decompensate at an early stage. That this failure is confined to the colon in diverticular disease is suggested by the normal response to distension of the rectal wall.

This finding is in no way incompatible with the observation that there may be an increase in intraluminal pressure changes in diverticular disease (Arfwidsson, 1964; Painter and Truelove, 1964; Parks and Connell, 1969). The two functions of resistance to stretch and intraluminal pressure are only distantly related. The resistance to a stretching force of the bowel wall is an approximation to the mean ‘tone’ of the segment studied (Farrar and Davidson, 1960), while intraluminal pressure measurements are an index of the ability of the bowel to form pressure segments (Connell, 1965). Intraluminal pressure measurements are a function not only of muscular contraction but also of factors such as the nature of the gut content, the contour and outline of the bowel, and the diameter of the segment from which recordings are taken (Part I).

The early decompensation of the muscle of the diverticular segment when submitted to a stretching force is surprising in view of its structure. Probably the best way to regard this muscle is that it is in a state of contracture (Williams, 1965). *A priori*, it might be thought that it would have a high resistance
to distension, but it now seems we must revise this concept and regard this muscle as functioning to nearly the limits of its performance and unable to cope effectively with the stretch presented by a luminal bolus.

Whether this feature of the muscle is the cause or the effect of diverticular disease it is not possible to say, as these studies were conducted in patients with established disease. In such a state, however, the likelihood of further herniation of mucosa is enhanced. The poor compensatory powers of the diverticular muscle must be considered in planning surgery, and, in particular, the operation of sigmoid myotomy must be reassessed in the light of these findings as it results in greater weakness of the wall of a colon already defective in terms of its resistance to stretch.

The presence of a large balloon in the lumen may be regarded as simulating a faecal mass. The desire to defaecate was stimulated more readily by distension of the colon than the rectum and patients with diverticular disease developed a desire to defaecate more readily than normal subjects. This may be because of the narrower diameter of the colon of the diverticular patients and the increased sensitivity due to inflammation.

SUMMARY

The muscle of a colonic segment bearing diverticula decompensates rapidly when subjected to a stretching force.

Sensations of pain or the call to stool arise more readily in a diverticular than in a normal segment.

We wish to thank Dr F. Avery Jones, Dr T. D. Kellock, Central Middlesex Hospital, and Professor H. W. Rodgers for permission to study patients under their care. We also wish to thank Miss Myrtle Boal and Mrs V. Blair for assistance with the tedious task of analysing records. We are grateful to Dr J. J. Misiewicz for contributing data on 10 of the patients studied by the miniature balloon method.

REFERENCES


