THE INTRAINTESTINAL PRESSURE AND FACTORS DETERMINING ITS MAGNITUDE

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Experiments on polyfistulous dogs showed that the pressure measured in the lumen of the small intestine by open-ended catheters oscillates within 50 and 1500 mm Hg at a frequency corresponding to the frequency of contractions of the smooth muscle of that segment of the intestinal wall. The pressure recorded is not systemic but is characteristic only of one of many segments existing simultaneously and changing continuously in size, in each of which the changes in pressure may take place independently. Experiments on models showed that essential conditions for the development of high pressures are the closure of the segment and the "functional rigidity" of its wall, i.e., its inextensibility at that particular pressure.

Many attempts have been made to measure the intraintestinal pressure because its fluctuations are considered to reflect faithfully the character of the intestinal movements [2-4, 6, 7, 9] and to have a direct effect on the intensity of absorption in the intestine [1, 5, 8]. It is assumed that open-ended catheters, introduced into the lumen of the small intestine, reproduce the fluctuations of systemic pressure in the same way as catheters inserted into blood vessels. The question arises to what extent these assumptions, based on analogy, are valid, i.e., to what extent an open-ended catheter, introduced into the lumen of the intestine, measures the true systemic pressure.

The investigation described below was carried out to study this problem.

EXPERIMENTAL METHOD

In experiments on polyfistulous dogs various types of open-ended catheters were passed through intestinal fistulas into the portions of the small intestine to be studied. In model experiments (shown schematically in Fig. 1) the intestine was simulated by a rubber tube. One end of the tube 1 was fitted over the first branch of a metal four-way tube 2, while the other end of the rubber tube 3 was connected through the three-way tube 4 to the funnel 5. The catheters 7 and 8 were introduced through the second branch 6 of the four-way tube. The third branch 9 was connected to an electromanometer 10 and the fourth branch 11 was used for filling the system with fluid. The pressure in the system was measured either by mechanical compression or by injecting an excess of fluid under pressure from a Janet's syringe 12.

The pressure in the intestine and in the model was recorded by electromanometers of the capacitor type giving linear measurements within the range from 0 to 1500 mm water. The recorder used had inertialess transmission with a frequency up to 100 Hz.

EXPERIMENTAL RESULTS AND DISCUSSION

The results of the experiments on the polyfistulous dogs showed that open-ended catheters, however close together they are, as a rule record different fluctuations of pressure (Fig. 2A). Only by prolonged recording were short periods observed during which all three catheters recorded identical changes in pressure, even when the catheters were 10 cm apart (Fig. 2B). Comparison of the pressure curves obtained by recording with a catheter enclosed in a perforated cover and with ordinary open catheters located in

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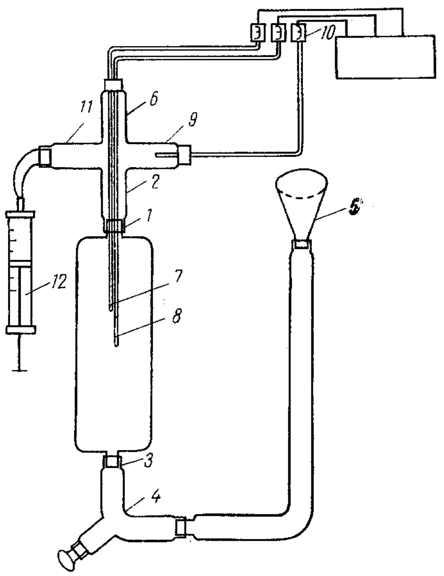

Fig. 1. Scheme of model: 1) first end of rubber tube; 2) metallic four-way tube (first branch); 3) second end of rubber tube; 4) glass three-way tube; 5) glass funnel; 6) four-way tube (second branch); 7-8) transducers; 9) four-way tube (third branch); 10) electromanometer; 11) four-way tube (fourth branch); 12) syringe for filling system.

the same segment of the intestine (one with the opening at its end, the other with the opening in its side) showed that the pressure recorded with the protected catheter was significantly higher than that measured by the two neighboring catheters in amplitude (Fig. 2C). The fact was noted that the tonic component was lower than in the recordings made with the unprotected catheters (Fig. 2D). If one of the pressure-measuring channels was connected directly to the fistula connected to the funnel, the intraintestinal pressure measured depended on the watertightness of the system. With the funnel open, so that the contents could enter freely into it during contraction, the pressure remained low (5-20 mm water), throughout the period of observation. In the closed system (with the funnel clamped) the pressure recorded in it rose sharply (Fig. 2E) to reach the value recorded with the other channels.

The results of these experiments were fully confirmed on the model of the intestine (Fig. 3A, B, C). A rapid rise of pressure was observed in the closed rubber tube only at the limit of its elasticity, either because of injection of a large volume of fluid or of complete compression of much of the tube (Fig. 3D). If the tube was divided into short segments not communicating with each other, the pressure change in each was recorded independently in response to compression of each segment of the tube in turn (Fig. 3E).

If a tube lined internally with Porolon was used and compressed locally at the point corresponding to the hole in the catheter surrounded by Porolon, the pressure recorded with this catheter was much higher than that recorded by a neighboring catheter in the lumen (Fig. 3F).

These experiments showed that a high pressure is produced in a segment of the rubber tube only if the segment is closed and the wall is stretched to the limit of its elasticity, i.e., at the pressure at which it becomes inextensible. Hence it follows that considerable increases in the intraintestinal pressure (up to 1360 mm water) recorded in the small intestine synchronously with its contractions can arise only in closed segments whose wall has become functionally "rigid," i.e., inextensible at that particular pressure.

The true magnitude of the intraintestinal pressure can thus be estimated by the use of open catheters

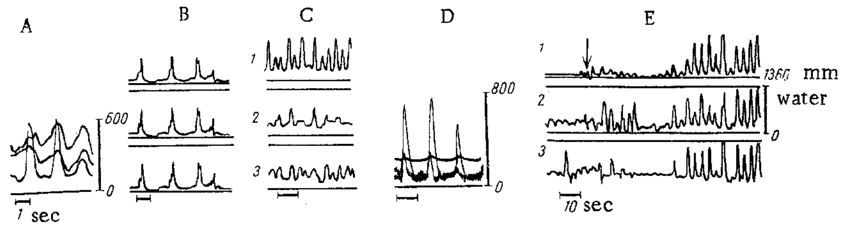

Fig. 2. Record of intraintestinal pressure obtained with different types of open catheters: A) record of pressure with three polyethylene open catheters cut across in the same plane; B) long record of pressure measured with open catheters; C) record of pressure measured with catheter protected by a cover (1), catheter with side opening (2), and open-ended catheter (3), 0.5 cm apart; D) record obtained with three open catheters 10 cm apart; E) record of pressure measured with open catheters before and after clamping funnel connected to fistula: 1) pressure in fistula, 2) pressure measured with catheter with side opening, 3) pressure measured with open-ended catheter. Arrow indicates time of clamping funnel.

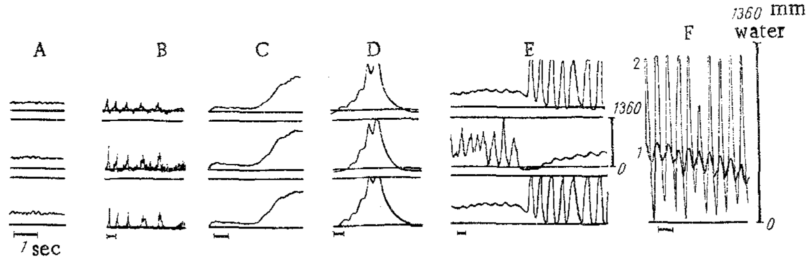

Fig. 3. Recording pressure with open catheter in experiments on the model: A) pressure in rubber tube recorded during injection of fluid into it with an open system; B) pressure recorded during injection of fluid into closed rubber tube (funnel clamped); C) pressure recorded during compression of a large part of the closed rubber tube (funnel clamped); D) rapid rise of pressure in distended, closed segment of rubber tube during injection of fluid into it; E) pressure recorded in neighboring separate closed segments of rubber tube during compression of each of them in turn; F) pressure recorded in open catheters inside the lumen of the rubber tube (1) and in Porolon lining its wall (2) during local compression of Porolon opposite hole in catheter.

only if the possibility of simultaneous contact between all the orifices of the catheter and the intestinal mucosa is ruled out (in the present experiments, by the use of catheters with a perforated cover). The intestinal segments varied considerably in size (from 1 mm to 20 cm) but, as a rule, they were quite small. Such a segment could be formed between the edges of the hole in the catheter and the mucous membrane of the intestinal wall. Under these circumstances fluctuations of pressure in the juxtamural layer of fluid, which differs from the intraintestinal pressure in the lumen of the digestive tube, could be measured. The facts described above are evidence that there is no such thing as a systemic intraintestinal pressure, for there is no such thing as a single, continuous lumen.

By using an open catheter for recording it is possible to study changes in pressure only in one of the many closed segments which exist at any one time and which are constantly changing in size, for the changes in pressure in each segment may take place independently. Hence it follows that, first, an idea of the true value of the fluctuations in intraintestinal pressure can be obtained only by averaging the values recorded over a considerable period of time. It is extremely important to obtain such information considering the possible role of fluctuations of hydrostatic pressure in the regulation of absorption in the small intestine. Another no less important factor is the functional heterogeneity of the various parts of the small intestine, reflected in the fact that wide variations in the intraintestinal pressure are found at any one time in its different portions. That is probably why the intestine as an organ can evacuate its contents and, at the same time regulate the rate of absorption of nutrient substances.

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