Effect of Hydrostatic Pressure on the Experimental Production of Ulcers

By

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IT has been demonstrated that intraintestinal pressure varies considerably in dogs and man. For example, Abott et al. (1) reported for man a basal "tonus pressure" of 11 to 15 cm. H_2O, with peristaltic waves raising it to 20 or 30 cm. H_2O, and occasionally to 60 cm. H_2O. Sherrington (2) found a normal pressure of 2 to 4 cm. H_2O in the intestine of etherized dogs which was confirmed by Owings et al. (3) and Sperling et al. (4). The latter group found the intraintestinal pressure in man to be 20 cm. H_2O in simple obstruction and about 30 cm. H_2O in simple obstruction with peristalsis. Seventy-five cm. H_2O was found in closed obstruction (3). An unusual observation was made by Stone and Firor (5) on two patients whom they were treating for ulcerative colitis. In the course of the treatment, a temporary complete obstruction was made in the lower ileum affording an opportunity to measure intraintestinal pressure at a known time after the obstruction was produced. This measurement was made by thrusting into the intestine a hollow needle connected to a water manometer. In both cases five hours after the bowel had been closed the pressure exceeded 150 cm. H_2O.

In a previous paper (6) we reported the production of ulcers in the intestine of dogs by exposing a loop of the intestine to a solution of 0.1 per cent pepsin in N/10 HCl with just enough pressure to cause a flow of about 2 cc. per minute.

The high incidence of intestinal distention prompted us to determine whether hydrostatic pressure influences ulceration of the alimentary tract in dogs.

METHOD AND TECHNIQUE

Dogs were anesthetized with Dial-urethane,* the abdominal wall incised and a loop of the small intestines about 18 inches long was selected which reached from the mid-portion of the duodenum to approximately the junction of the upper third with the middle third of the jejunum. Both ends of the loop were cannulated so that solutions could be introduced into it and withdrawn at will. The loop was then replaced into the abdomen and exposed to a solution of 0.1 per cent pepsin in N/10 HCl under various hydrostatic pressures. The pepsin solution in the loop was drawn off hourly and fresh solution was added simultaneously without a marked change in the pressure. The loops were exposed for 360 to 720 minutes or until perforation occurred which could be noted by a rapid fall in the solution in the column. The loops were then removed and examined for damage.

The pressures employed were 0, 45, 90 and 135 cm. H_2O, and the results are given in Table 1 along with control experiments using isotonic saline instead of the pepsin solution at pressures of either 90 or 135 cm. H_2O.

In all cases where 0.1 per cent pepsin in N/10 HCl was used there was some necrosis of the intestinal wall. At zero pressure the usual picture was a necrosis covering about one-third of the total area of the loop and extending in some instances to the serosa but in most cases only through about one-half of the mucosa. In all cases but two where hydrostatic pressure was used a perforation occurred and the damage was progressively worse as the pressure was increased. The time for perforation to occur became less as the pressure was increased as shown in Table 1. One dog at 45 cm. hydrostatic pressure with pepsin solution died at the end of 300 minutes with no perforation. One dog also died with no perforation at the end of 300 minutes in the 90 cm. hydrostatic pressure experiments with pepsin solution. The incision was made in the latter dog before he was in deep anesthesia, and the abdominal musculature was somewhat spastic rendering the intra-abdominal pressure considerably higher than usual, which in our opinion, accounted for the delay in perforation.

In controls exposing the gut to 90 or 135 cm. hydrostatic pressure with physiologic saline there was no perforation even though the exposure was for 120 to 720 minutes. These loops were atonic and stretched but showed no necrosis.

DISCUSSION

It is suggested that the pronounced effect of hydrostatic pressure on ulcer formation is due to three factors: 1. Mechanical stretching. The length and the diameter of the loop were increased by about one-third thereby causing a thinning and weakening of the intestinal wall. 2. Decreased blood supply. Landis (7) found the mesenteric capillary pressure in the rat to be 30 cm. H_2O and in the guinea pig 38.5 cm. Since it is quite likely that the capillary pressure in the intestine of dogs is of this order, it is evident that the pressure employed by us, either 90 or 135 cm. is sufficient to cause a marked retardation of blood flow even though the intestine may have some ability to recover its blood flow after its interruption by inflation of the loop (8, 9). 3. Increase in penetrability of pepsin. It has been reported that high hydrostatic pressure increases absorption in the intestine (10, 11), facilitating the absorption of substances not readily absorbed (10). By using various chemical agents which influence ab-

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sorption, Driver, et al. (12) were able to increase the incidence of ulcers over controls, and it is probable that in the experiments reported here, pepsin penetrated into the mucosa and deeper layers of the gut more readily under pressure.

In connection with these investigations the high incidence of ulcers among aviators is of considerable interest. In this group the neurogenic factor undoubtedly plays a major role in the etiology of ulcers, but it must be equally true that the intra-gastric and intra-intestinal distention to which aviators are subjected, particularly in rapid ascent after uncontrolled diet, contributes to the severity of the damage to the alimentary tract wall.

SUMMARY

1. Loops of intestines of 48 dogs were exposed to 0.1 per cent pepsin in N/10 HCl under various hyrostatic pressures.

2. A rise in intraintestinal pressure resulted in a marked increase in the extent of peptic digestion which led to perforation in a short time. At 45 cm. pressure the average time for perforation was 300 minutes; at 90 cm. pressure, 82 minutes; and at 135 cm. pressure only 41 minutes.

TABLE I

Effect of Hydrostatic Pressure on Ulcer Formation

Solution	Hydrostatic Pressure	Number Dogs	Number Perforations	Time Exposed (minutes) Average	Range
O./% pepsin* in N/10 HCl	0	15	0	685	360-720
"	45	10	9	300	65-565
"	90	11	10	82	60- 90
"	135	12	12	41	13- 70
0.9% NaCl	90	6	0	630	495-720
"	135	6	0	445	495-720

*Merck N. F. Powdered

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Increased Intra-Abdominal Pressure as a Means of Inhibiting Perforations Due to Pepsin Solutions Under Hydrostatic Pressure in the Small Intestines of Dogs

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IN previous papers we have shown that 0.1 per cent pepsin in N/10 HCl produced more necrosis in the small intestine when hydrostatic pressure was applied than when the pressure was just sufficient to permit a flow of about 2 cc. of solution per minute (1, 2). Perforations occurred in an average of 41 minutes with

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