

direct parallelism was noted between surviving rate and ulcer occurrence in steroid treated fasting rats.

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Influence of Hypothermia on Secretory Activity of Rabbits' Appendix and on Closed Duodenal Loops.* (24863)

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Experimental observations previously reported demonstrated that rupture of obstructed appendix in rabbits, chimpanzees and man was caused by early development of high intraluminal pressures resulting from rapid rate of appendical secretion(1,2). In a large series of observations upon other species in which activity of appendix was examined, only in chimpanzee and man was there evidence of active secretion. Morton and Sullivan(3) compared closed jejunal loops with similar ones in the ileum. The intra-enteric pressure of jejunal loops (52 cm of water) was 7 times that developed by ileal (8 cm) segments. They concluded that the jejunum secreted more rapidly than the ileum. No observations of duodenal secretory activity were made. Recent observations(4) from this laboratory showed that local gastric cooling in a variety of species, including man,

reduced gastric secretory activity and proteolytic digestion. This suggested that the influence of hypothermia upon secretory activity of the obstructed appendix and of closed duodenal loops should be assessed.

Methods. Adult white rabbits weighing 1.5 to 2.0 kg were anesthetized and opened by midline abdominal incision. Appendical closed loops were established by ligating base of appendix with umbilical tape. Closed duodenal loops about 8 inches long were made by occluding the lumen with ligatures at 2 sites to exclude biliary and pancreatic secretions. Integrity of the vascular arcades of these segments was carefully preserved. Rate of appendical secretion was investigated using the simple closed loop described above and in a modified preparation. In the latter, so that secretions could be collected with minimal change in intraluminal pressure, the appendix was cannulated with a plastic tube to which a condom was attached. Duodenal secretions were collected only from unmodified closed loops. In those rabbits that were used for in-

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TABLE I. Volume of Secretion from Appendix and Duodenal Closed Loops in 6 Hours. (6 rabbits used in each temperature range.)

	Systemic temp. °C			Local temp. °C	
	38	27-30	21-24	38	15
<i>Appendix</i>	ml				
Without drainage					
Mean	10.5	3.8		16.0	6.6
Range	9-12*	2-7		14-18*	3-11
With drainage					
Mean	17.2	3.7		18.3	4.5
Range	11-24.5	2-6		15-22	4-5
<i>Duodenum</i>					
Without drainage					
Mean	36.5		3.5	44.5	4.3
Range	35-38		3-4	32-51†	4-5

* 3 perforations.

† 2 "

traduodenal and intra-appendical pressure determinations, a #280 polyethylene catheter 2.5 mm in diameter was inserted into the lumen, the remainder of tube raised vertically to act as pressure manometer. In all animals undergoing systemic hypothermia as well as in normothermic controls, the obstructed segment of bowel was returned to abdominal cavity and the incision closed. In animals in which appendixes or closed duodenal loops were to be cooled locally, the portion of bowel to be studied was kept outside the abdominal cavity. Controls were employed for this latter group by exteriorizing the appendix or closed duodenal loop and warming it externally to 38°C. General body hypothermia was achieved by briefly immersing animals in ice water. Local hypothermia or normothermia of obstructed loops was provided by circulating cool or warm (38°C) solution of desired temperature through plastic bags in close approximation to exteriorized segment. The bags were arranged in such a way that they exerted only minimal pressure on obstructed loop. All studies, both secretory and manometric, were uniformly 6 hours long.

The results of experiments with rabbit appendix are shown in Table I. These observations indicate that both local and systemic hypothermia markedly reduced rate of secretion. Volumes secreted by obstructed appendixes, whether drained or closed loops, during systemic hypothermia were essentially the

same. Normothermic appendixes secreted 3 to 5 times as much as cooled appendixes during similar time periods. A reduction in secretory volumes of equal magnitude was attained in drained appendixes cooled locally.

Among 12 rabbits of control group there were 6 perforations attending obstruction of appendix, an incidence of 50%. Appendical pressure studies (Table II) parallel the finding of decreased volumetric secretion in hypothermic appendixes. Pressures in group undergoing systemic hypothermia, after 6 hours of obstruction, are uniformly lower than those in normothermic control group. Mean pressure in former is approximately one-fifth that recorded in latter group. Similar observations were made in comparing secretory rates of appendixes where temperature was controlled locally.

Perforation of the appendix occurred in 8 of 12 normothermic rabbits of control groups for pressure experiments, an incidence of 66%. Five of 8 occurred in appendixes locally warmed, (38°C) outside abdomen, while the remaining 3 were observed in animals at normothermic systemic temperatures (38°C). Perforation was not observed in cooled appendixes.

Data in Table I demonstrate that volume of duodenal secretion is reduced markedly by systemic and local hypothermia. In fact, volumes secreted during either form of hypothermia are only about one-tenth as large as those secreted under normothermic (38°C) conditions. Spontaneous duodenal perforation at sites away from ligatures and within limits of experimental period, occurred in 2

TABLE II. Pressure Developed in Appendix and Duodenal Closed Loops in 6 Hours. (6 rabbits used in each temperature range.)

	Systemic temp. °C			Local temp. °C		
	38	27-30	22-27	38	20	15
<i>Appendix</i>	cm					
Mean	67.5	13.2		82.8		8.0
Range	42-84*	7-21		72-98†		3-15
<i>Duodenum</i>						
Mean	70.5		8.4	61.9	11.5	
Range	53-87		5-13	42-75†	7-18	

* 3 perforations.

† 5 "

‡ 1 "

of the 6 exteriorized duodenums locally warmed. There were no perforations in normothermic obstructed duodenal loops that remained within the abdominal cavity, or in any of those kept hypothermic, whether in or out of the abdomen. The data in Table II show that both systemic and local hypothermia virtually stopped the rise of pressure in duodenal closed loops. Perforation of the duodenum occurred in one animal undergoing local warming when the intraluminal pressure reached 75 cm of fluid.

Discussion. Our earlier studies(5) showed that maintenance of an intraluminal pressure of 40 cm of water caused portions of a jejunal closed loop to become nonviable within 20 hours. Nonviability and perforation of obstructed appendix occur in a much shorter time because of rapidity of elevation and the magnitude of intraluminal pressures (up to 136 cm of water). Pressures such as these cause perforation through agencies of venous stasis, ischemia and finally necrosis of areas of bowel wall. The duodenal closed loop also has a strong secretory capacity, being able to achieve high intraluminal pressures within a few hours. Some areas of duodenal wall in these segments, appeared somewhat dark and ischemic at end of 6 hours; one externalized, locally warmed and 2 intra abdominal normothermic duodenums perforated spontaneously. The low incidence of perforations in this group, when compared with the great frequency of perforation in the obstructed appendix is attributable, undoubtedly, to lower intraluminal pressure ranges developed in closed duodenal loops. Blood pressure carefully monitored during cooling, in a number of animals undergoing either appendical or closed duodenal loop obstruction, showed that cooling caused blood pressure falls of only

about 5 mm of Hg, when recorded at temperatures between 28° to 31°C. Depression of blood pressure was therefore not responsible for the observed reduction in rate of secretion in locally cooled appendixes in otherwise normothermic rabbits. Studies of blood flow in locally cooled appendix or duodenum have not been made. However, we observed that local gastric cooling to 15°C in the dog is attended by mean reduction in gastric blood flow of 66% (unpublished). Undoubtedly, a similar occurrence attends local cooling in other portions of bowel. Diminished blood flow and decreased cellular activity of actively secreting epithelial cells are probably the agencies essentially responsible for the observed decrease in secretion and intraluminal pressure in closed segments of duodenum and in the obstructed appendix.

Conclusions. (1) In rabbits, hypothermia reduces rate of secretion in duodenal and appendical closed loops. Depression of secretion is reflected in failure of these loops to attain high intraluminal pressures found in normothermic control animals. (2) Local and systemic hypothermia prevented perforation of obstructed appendix or closed duodenal loop in the rabbit.

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