

MORPHOLOGICAL AND PHYSIOLOGICAL CHANGES IN THE SMALL INTESTINE OF THE DOG AFTER ITS PARTIAL RESECTION

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In experimental investigations dealing with resection of the intestine it has been discovered to what extent the intestine may be resected without any material harm being done to the animal [2, 8], how the assimilation of the principal food substances proceeds after this procedure [1, 2, 4] and how the movements of the residual portion of the intestine are altered [5]. V. P. Mandzhgaladze [3], studying the enzyme-secreting function of the intestine, found that after resection of the proximal or distal divisions of the small intestine there is an increase in the concentration of enzymes per 1 g of solids in the intestinal juice secreted by the isolated portion. The percentage ratio of the solid part of the juice is diminished after resection of the proximal division, and increased after resection of the distal division. In these experiments the isolated area corresponded to the section of intestine removed and not to the residual portion. Nevertheless it would be of the utmost interest to trace the restoration of the function of the residual portion of the small intestine and the isolated area corresponding to it.

The question of the time of development of the compensatory reaction arising after removal of a portion of the intestine has not been discussed, and in connection with the character of the morphological changes taking place under these conditions the findings are contradictory.

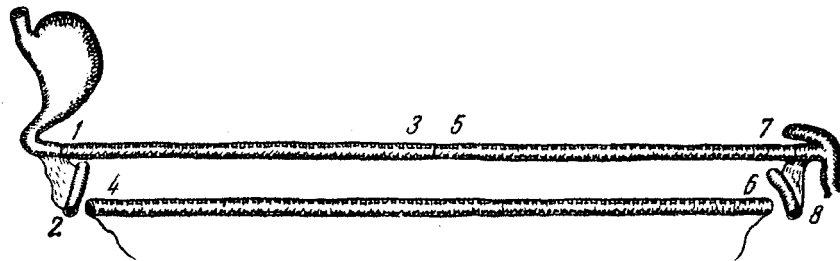
In view of the interdependence of structure and function in the intestine we undertook a morphological and physiological investigation of the changes arising in the small intestine after partial resection of that organ.

EXPERIMENTAL METHOD

Two areas of the intestine were isolated in 5 dogs by Thiry's method; one immediately after an area of the intestine with a short mesentery, the other at a distance of 10 cm from the ileocaecal angle. The periodic secretion of intestinal juice in the course of 4 hours was studied (18 hours after taking food). The volume of juice and the proportions of solid and liquid parts were noted. The juice was homogenized and its enterokinase content was determined by Shlygin's method [7] and its alkaline phosphatase content by the method of Fomina, Mikhlin and Shlygin [6]. After establishing the basic level of the intestinal secretion (in 8-10 experiments on each dog), and after starvation for 24 hours, from $\frac{1}{3}$ to $\frac{1}{2}$ of the middle portion of the small intestine of the dogs was resected. On the 2nd-3rd day after operation, and subsequently every 1-3 days, the dogs were mounted on the apparatus. In addition, half the small intestine, from the middle portion, was resected in 6 dogs without the preliminary formation of isolated areas.

At different times from 2 weeks to 6 months after operation the dogs were killed by means of an electric current. Before slaughter the dogs were starved for 24 hours. During the operation and after slaughter pieces of intestine were removed from the dogs for histological examination in accordance with the following scheme (see Figure).

In order to investigate the enzymes a 1:5 aqueous extract was prepared from scrapings of the mucous membrane (time of extraction - 30 minutes), and its enterokinase and phosphatase contents determined. For the histological examinations the material was fixed in 12% formalin solution and then embedded in paraffin wax. Sections were cut to a thickness of 10 μ and stained with hematoxylin - eosin.



Scheme of the operation - resection of the intestine and removal of samples for histological examination. 1) Beginning of the jejunum; 2) anterior isolated area; 3) midpoint of the jejunum; 4-6) resected area; 5) midpoint of the ileum; 7) end of the ileum; 8) posterior isolated area. Areas 1 and 2, 3 and 4, 5 and 6, 7 and 8 were compared.

EXPERIMENTAL RESULTS

The periodic secretion of intestinal juice and its enzymic activity. The volume of juice secreted from the anterior isolated area was only slightly changed after the operation, as shown by Table 1 in which the mean values for each dog taking part in the experiment are given.

The volume of juice secreted from the posterior isolated area of dogs Nos. 1 and 4 fell after a prolonged postoperative period (2-6 months); this may be connected with the fact that this particular area begins to be epithelialized from the surrounding skin and is gradually overgrown. In the same dogs, as time went on the proportion of solid matter in the juice rose (Table 2). The increase in secretion in dog No. 5 can be accounted for by prolapse of the mucous membrane of this isolated area. Where the isolated area of intestine was in good condition (as in dogs Nos. 2 and 3) the secretion was not appreciably changed.

TABLE 1

Mean Volume of Intestinal Juice (in grams) During 4 Hours' Secretion

Dog No.	Area of intestine			
	anterior		posterior	
	before operation	after operation	before operation	after operation
1	5,28	4,60	3,52	2,28
2	2,78	4,83	2,0	1,53
3	6,81	5,68	4,47	4,56
4	3,66	3,98	2,03	0,62
5	3,45	2,98	0,87	2,01
Average for all dogs	4,37	4,41	3,33	2,79

The proportions of the solid and liquid parts of the juice were essentially unchanged after the resection (Table 2).

The findings in connection with the enterokinase content of 1 g of the solid part of the intestinal juice secreted from the anterior isolated area before and after resection are given in Table 3.

TABLE 2

Mean Percentage Value of the Solid Component of the Intestinal Secretion Before and After Resection of the Intestine

Dog No.	Area of intestine			
	anterior		posterior	
	before operation	after operation	before operation	after operation
1	30,9	37,5	30,0	28,4
2	45,6	26,5	28,0	50,3
3	32,9	40,0	41,4	35,7
4	49,5	43,7	35,4	79,1
5	43,4	61,3	59,1	47,5
Average for all dogs	40,4	41,8	38,7	40,9

TABLE 3

Mean Number of Units of Enterokinase in 1 g of Solids in the Intestinal Juice

Dog No.	Before operation	After operation
1	774	710
2	863	984
3	447	533
4	470	521
5	726	509
Average value for all the dogs	656	651

TABLE 4

Average Number of Units of Alkaline Phosphatase in 1 g of Solids in the Intestinal Juice

Dog No.	Area of intestine			
	anterior		posterior	
	before operation	after operation	before operation	after operation
1	20 000	49 300	11 400	9 200
2	70 100	96 400	10 600	20 900
3	73 200	525 700	19 700	123 500
4	63 500	386 600	9 100	70 000
5	477 300	757 000	37 000	66 500
Average for all dogs	140 900	363 000	17 600	58 000

As seen in Table 3, the enterokinase content varied between approximately the same limits before and after resection. The volume of juice and the proportion of solids were not appreciably altered, and so the number of units of enterokinase during secretion for 1 hour remained the same after operation as it had been before.

There was a change in the phosphatase content in the form of an increase in its concentration per gram of solid matter and per hour of secretion in both the anterior and posterior isolated areas. The mean values for each dog taking part in the experiment are given in Table 4.

We observed an increase phosphatase content of the intestinal juice even in the first few days after resection, i.e. on the 2nd-3rd day, when for the first time after the operation the dog was mounted on the apparatus. Later on the phosphatase content fluctuated but did not fall below the upper limits of normal.

The enzymic activity of the mucous membrane. The enterokinase concentration in the mucous membrane of the small intestine began to rise in the 2nd-3rd weeks after resection of the intestine, reaching a maximum after 1-2½ months (a two- or threefold increase). The increased enzymic activity was maintained for 6 months after operation. In respect of the phosphatase activity of the mucous membrane no definite regular relationships could be demonstrated.

Morphological modifications in the intestinal wall. At necropsy of the experimental animals roughly one month after operation some increase in the diameter of the intestine and some thickening of its wall could be seen. Kerkring's folds were more pronounced than during the resection. This was especially noticeable in dogs in which the postoperative period was from 2 to 4 months.

On microscopic examination we discovered hypertrophy of the mucous membrane. Measurements showed that the mucosa of the portion of intestine remaining after resection (beginning 1 month after operation) was from 20-30% thicker than the mucosa of the resected area of intestine of the same dog. This thickening was due to a proportionate lengthening of the villi and crypts. Kerkring's folds also became much thicker and longer after operation. The number of cells in the same extent of the epithelial layer of the villi in the resected part differs hardly at all from their number in the remaining portion of the intestine at whatever time the animals were killed. From this it may be concluded that the process of hypertrophy of the mucous membrane takes place on account of hyperplasia of its cellular elements.

Hypertrophy is noted in some dogs only 2-3 weeks after the operation, reaching a maximum after a period of 2 months, and it is observed in both the jejunum and ileum.

The processes of morphological modification almost pass by the isolated areas; the thickness of the mucosa of the isolated areas was from 20-40% less than the thickness of the mucosa of that section of the intestine from which the area had been isolated.

On the basis of our experiments we cannot conclusively decide whether an increase takes place in the total number of villi. This can only be judged after a study of intestine which has been fixed in an atonic state.

In comparing the findings on the morphological and enzymic changes, attention is drawn to the fact that the degree of morphological modification does not always correspond to the degree of stimulation of enzymic activity. Evidently the processes of functional compensation and of morphological modification supplement each other.

The mucosa of the isolated areas reacts differently to resection of the intestine from the mucosa of the residual portion of the intestine.

It may be postulated that the restorative processes in the intestine after resection are directly influenced by the passage of food masses.

It may be concluded from the results obtained that after resection of the middle part of the intestine both the jejunum and the ileum take part in the restorative processes.

SUMMARY

About $\frac{1}{3}$ to $\frac{1}{2}$ of the middle part of the small intestine was resected in dogs. Secretion of the juice by the isolated portions of jejunum and ileum, as well as the content of enterokinase do not change after the resection. The activity of basic phosphatase in 1 gm of the solid part of intestinal juice per hour of secretion increases by 2-3 times after the resection. The content of enterokinase in the scrapings of the mucous membrane of residual part of intestine increases by 2-3 times in a month after the operation. By this time the thickness of the mucous membrane is increased by 20-30%. This is not observed in the mucous membranes of the isolated intestinal portions. Morphological change and increase of the fermentative activity were noted in the mucous membrane of the jejunum and ileum.

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