

# QUANTITATIVE CHARACTERISTICS OF REPAIR PROCESSES IN THE RAT STOMACH AFTER RESECTION OF THE FUNDAL PORTION

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In adult rats between 45 and 50% of the wall of the gastric fundus was removed. Marked hypertrophy of the mucous membrane of the gastric fundus was observed 3-6 months after the operation, and it was accompanied by a considerable and lasting increase in the number of oxyntic cells. The outer muscular layer was hypertrophied in the region of the fundus. However, restoration of the area of the mucous membrane was incomplete. The original ratio between the area of the mucous membrane of the fundus and pylorus was not restored.

Despite very thorough studies of the resected stomach in clinical practice, information on repair processes in the organ, obtained on the basis of biopsy and morbid anatomical material is evidently lacking. Experimental data on the morphology of the stomach after resection are very few. The most detailed investigations have been undertaken by Lazovskii and his pupils and followers [7, 8, 10-13], and by a few other workers [1, 2, 6, 14]. Without mentioning the well-known descriptions of repair processes in the resected stomach, it will suffice to mention that Lazovskii described a number of compensatory changes in the gastric stump. Bochkov [3, 4, 5] also carried out research in this field to study regeneration of the mucous membrane of the small intestine in dogs and rats after resection of 50% of the small intestine. He found that it is restored through endomorphosis [9]. This suggests that the mucous membrane of the stomach might be regenerated in the same way.

The objective of the present investigation was to determine the quantitative characteristics of repair processes in the resected stomach.

## EXPERIMENTAL METHOD

Between 45 and 50% of the wall of the gastric fundus was resected in the region of the greater curvature in 125 noninbred male rats weighing 170-250 g (Fig. 1). The animals were anesthetized by intraperitoneal injection of 0.4 ml of 1% pentobarbital sodium per 100 g body weight. The animals were kept on a bland diet for 10 days after the operation. They were sacrificed 3 days, 1, 2, and 3 weeks, and 1, 1½, 2, 3, 6, and 9 months after the operation. A group of intact animals of the same age were sacrificed at the same time. The material was fixed by perfusing the stomach with Carnoy's mixture. Paraffin sections, 7 μ in thickness, were stained by the Dominici-Kedrovskii method. Using fixed material, the glandular portion of the stomach was weighed and the area of the mucous membrane measured. The area of the whole mucous membrane and the area of the fundus and pylorus were obtained by weighing cutouts of tracings of their outlines on graph paper. The thickness of the mucous membrane and of the circular muscle layer was measured on drawings of the sections magnified 30 times by means of a "Svet" projector. The results were subjected to statistical analysis.

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TABLE 1. Changes in Thickness of the Fundal and Pyloric Mucous Membrane after Resection of the Gastric Fundus

Time after resection	Thickness of mucous membrane (in conventional units)			
	fundus		pylorus	
	experiment	control	experiment	control
3 days	15.2	19.9	8.5	10.0
1 week	20.9		8.6	
2 weeks	18.6		8.6	
3 "	23.1	16.7	12.4	7.5
1 month	18.2		7.6	
1½ months	19.7		7.6	
2 "	14.6	16.1	7.7	-
3 "	21.4		7.6	
6 months	22.7		11.6	
9 "	24.6	21.8	9.5	10.7

TABLE 2. Changes in Thickness of the Outer Muscular Layer in the Fundus and Pylorus after Resection of the Gastric Fundus

Time after resection	Thickness of muscular layer (in conventional units)			
	fundus		pylorus	
	experiment	control	experiment	control
3 days	8.2	-	5.4	4.2
1 week	-	-	-	-
2 weeks	-	-	-	-
3 "	-	-	-	-
1 month	8.0	5.3	5.8	4.2
1½ months	8.7		8.1	
2 months	6.0		5.5	
3 "	11.4	2.7	6.0	-
6 "	17.4		11.6	
9 "	13.2		7.7	8.7

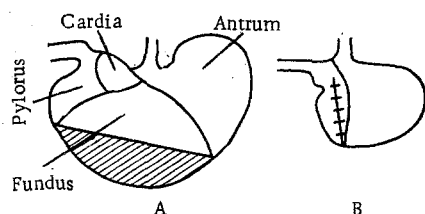


Fig. 1. Diagram of operation:  
A) rat's stomach before resection. Region to be resected is shaded;  
B) rat's stomach after removal of 50% of the wall of the fundus.

## EXPERIMENTAL RESULTS

The state of the animals during the first week after the operation was satisfactory. Until 2 weeks after the operation all the animals lost weight by as much as 11-20%. Histological examination of the residual part of the stomach showed that 3 days after resection the wound defect was filled by a fibrin clot, incorporating blood cells. After 1 week all traces of the fibrin had gone and were replaced by loose connective tissue, and the defect was epithelized. Nearer to the edge of the defect, primitive glands had formed. In some cases cysts lined with cylindrical or undifferentiated epithelial were observed. At this time the submucosa was highly edematous, and adhesions formed on the peritoneal surface of the stomach. Transient hypertrophy of the mucous mem-

brane of the fundus and pylorus was observed 3 weeks after the operation and was evidently reactive in character. By 1-1.5 months the number of cysts in the region of the defect showed a decrease. After 3 months hypertrophy of the mucous membrane of the fundus was observed, and it continued until 6 months after resection (Table 1). Differences from the control groups of animals of the same age were highly significant, amounting to 30-40% ( $P=0.004$  and  $0.027$ , respectively). The number of highly differentiated cells was increased in the glands of the hypertrophied mucous membrane (Fig. 2). However, summation of the results for the peptic cells obtained for the whole mucous membrane of the gastric fundus did not give sig-

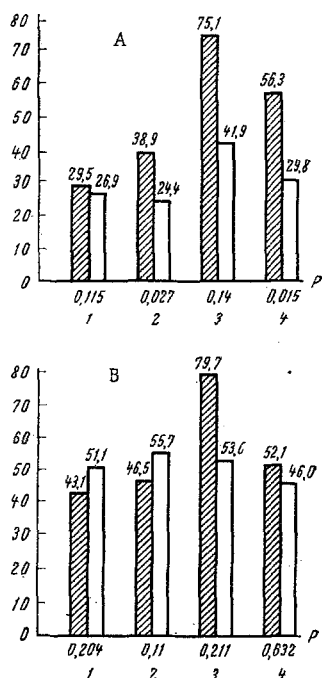


Fig. 2. Number of oxyntic (A) and peptic (B) cells in glands of the rat gastric fundus at various times after resection. Shaded columns represent experimental rats, unshaded columns control rats. Numbers above columns give mean number of cells in gland. Abscissa, time after operation; 1) 1 week, 2) 3 months, 3) 6 months, 4) 9 months; ordinate, number of cells.

nificant differences. It thus follows that the number of peptic cells in the glands of the residual part of the gastric fundus was not substantially changed. The number of oxyntic cells increased simultaneously with the onset of hypertrophy of the mucous membrane, and 6 months later it was almost twice their number in the control animals of the same age, on account of the hypertrophied areas. By 9 months these differences were the same, but the number of oxyntic cells was increased more uniformly in the various parts of the fundal mucous membrane, and the differences were significant ( $P=0.015$ ). At this time there was hardly any difference in the thickness of the fundal mucous membrane in the animals of the 2 groups. Six months after the operation, in some animals areas of hypertrophy of the mucous membrane lay alongside areas with atrophic changes in which the glands were few in number and short in length and did not contain highly differentiated types of cells. In some cases the hypertrophy of the mucous membrane was focal in character. No significant changes in thickness of the pyloric mucous membrane or in its structure were seen throughout the experiment. A study of changes in the thickness of the outer muscular layer (Table 2) in the region of the fundus revealed definite hypertrophy of the muscles: after 3 months it was 215%, and after 6 months 640% of the thickness of the muscular layer of control animals of the same age ( $P=0.008$  and  $0.003$ , respectively). After 9 months the degree of hypertrophy of the outer muscular layer was 220% compared with the control ( $P=0.012$ ). Practically no hypertrophy of the outer muscular layer was observed in the pyloric region.

After resection of the gastric fundus, the area of the gastric mucous membrane of the rats showed changes. Three days after the operation it was 40% of the area of the gastric mucous membrane of control animals of the same age, and 1 month after the operation it was increased to 60% of the control area. No further increase in the area of the mucous membrane occurred before the end of the experiment. Investigation of the area of the mucous membrane occupied by fundal and pyloric glands showed that in control animals weighing 200 g (at the beginning of the experiment) the ratio between the areas of the pylorus and fundus was 1:4, while in animals weighing 500 g (end of the experiment) it was 2:3. In the experimental rats, 1 month after resection of the gastric fundus and until the end of the experiment the ratio was 2:3, i.e., there was a premature relative decrease in the area occupied by the highly differentiated glands of the gastric fundus.

In the present experiments, after resection of a considerable part of the gastric fundus yet, at the same time, with preservation of the humoral and nervous relationships as far as possible in the residual part of the organ, repair processes were observed in it. However, the repair was incomplete: the area of the mucous membrane was not restored, and there was no return to the original ratio between the areas of the fundus and pylorus. Progressive changes took place, including hypertrophy of the mucous membrane, with an increase in the number of its gland cells, especially oxyntic cells, and also hypertrophy of the outer muscular layer of the gastric fundus. A tendency was observed for the mucus-forming function of the mucous membrane to be compensated, as was shown by an increase in the number of its mucus-secreting cells and also by the quantity of mucus in the apical ends of the cells and in the lumen of the pits of the glands. Pepsin formation was undisturbed after this operation. Only in some cases were cells almost completely free from pepsinogen granules observed, and the number of these highly differentiated cells was greatly reduced. Hence, despite the incompleteness of restoration of the gastric mucous membrane after resection, some degree of regeneration in fact takes place.

#### LITERATURE CITED

1. S. Ya. Arshba, in: Transactions of the Abkhaziya Medical Society [in Russian], Vol. 1, Sukhumi (1957), p. 21.

2. S. Ya. Arshba, Resection of the Stomach for Peptic Ulcer [in Russian], Tbilisi (1962).
3. N. P. Bochkov, in: Problems in Regeneration and Cell Division [in Russian], Moscow (1959), p. 149.
4. N. P. Bochkov, Byull. Éksperim. Biol. i Med., No. 3, 76 (1959).
5. N. P. Bochkov, in: Repair Processes in Vertebrates [in Russian], Moscow (1959), p. 111.
6. K. A. Zufarov, Current Problems in Adaptive Processes [in Russian], Tashkent (1970).
7. Yu. M. Lazovskii, O. F. Sharovatova, and M. M. Kogan, Arkh. Pat. Anat., 1, No. 1, 107 (1935).
8. Yu. M. Lazovskii, Functional Morphology of the Stomach under Normal and Pathological Conditions [in Russian], Moscow (1947).
9. L. D. Liozner, in: Problems in Regeneration and Cell Division [in Russian], Moscow (1959), p. 6.
10. N. A. Nilova, Byull. Éksperim. Biol. i Med., No. 12, 104 (1963).
11. N. A. Nilova, Morpho-functional Changes in the Glandular Apparatus of the Mucous Membrane of the Stump after Extensive Resection of the Stomach. Author's Abstract of Candidate's Dissertation, Moscow (1967).
12. E. A. Rudik, Experimental Reproduction of the Morphological Picture of Chronic Gastritis. Dissertation, Moscow (1939).
13. S. I. Filippovich et al., Compensatory Processes in the Digestive System after Resection of the Stomach and Small Intestine [in Russian], Moscow (1963), p. 209.
14. N. Henning, Die Entzündungen des Magens, Leipzig (1934).