COMPENSATION OF THE DIGESTIVE FUNCTIONS AFTER PARTIAL RESECTION OF THE STOMACH IN DOGS*

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The present work presents some results of investigations devoted to the problem of compensatory adaptation in the digestive system which has been studied in recent years by the laboratory team.

I. P. Razenkov's investigations into the features and mechanisms of digestive adaptation to qualitatively different diets [14] as well as to conditions of lowered barometric pressure [15] are well known.

Very valuable data have also been obtained on the question of compensatory functional and structural rearrangement of the digestive system in some pathologic conditions. In particular, clinically important data have been obtained on enhancement of the secretory function of the digestive tract in renal disorders and also on the morphologic and physiologic rearrangement of the gastric mucosa following removal of the pyloric part of the stomach or of the fundus and the body [13]. The latter studies, carried out in I. P. Razenkov's laboratories as early as 1938-1939 (Lazovskii, Sharovatova and Kogan), served as a premise for our elaboration of this question.

The problem of compensatory adaptation of the organism following various systemic lesions has attracted a great deal of attention both in the Soviet Union and abroad. One of the least thoroughly studied aspects of the problem is the mechanism of compensatory processes following "exclusion" of various parts of the gastrointestinal tract. The material available in the literature touches not so much on the mechanisms of compensation as on the characteristics of the changes in the activity of the digestive system following injury or "exclusion" of its parts, in particular resection of the stomach.

In addition to extensive clinical literature (Gordon [1949, 1951, 1957], Shlapoberskii and Neporent [1945], Neporent [1956], Abarbanel [1938, 1950], Shekhter [1946], Neimark [1956], Vitkin [1936], Raiz [1949] etc.) there are also some experimental works dealing with this subject (London et al. [1911-1913], Ivy et al. [1931-1940], Kanshin [1939], Hertel [1930], Everson [1952-1954], Mann, Graham [1932], Seleznev [1955], Petrov [1955] etc.). A number of theoretical questions concerning the dynamics and mechanisms of functional compensation following extensive resection of the stomach still remain unanswered; these include the following: whether compensation occurs as the result of regeneration and restoration of function of the affected organ or as the result of other parts of the system taking over the function; the nature of the inter-relationship of local and central regulatory mechanisms in compensatory reactions; the inter-relationship of functional and structural compensation, etc.

We therefore posed the following problems: 1) to demonstrate concrete forms of compensatory reactions following resection of the stomach in long-term experiments on dogs; 2) to trace the dynamics of compensatory reactions over a long period of time postoperatively, making a study of the degree and order of inclusion of various organs and functions of the digestive system into the process of compensation; 3) to elucidate the mechanisms of the compensatory process and agents which would stimulate it.

* In honor of the 70th birthday of the eminent Soviet physiologist Ivan Petrovich Razenkov the Editors have included in this section of the journal a number of works on the physiology of digestion carried out in recent years by a team of collaborators.

EXPERIMENTAL METHOD

The first results were obtained by us in long-term experiments on 28 operated dogs (with gastric and intestinal fistulas, exteriorized pancreatic duct and isolated loops of the small intestine) 22 of whom had been subjected to gastric resection. Control experiments were carried out on 6 dogs.

The following determinations were made: secretion and enzyme production of gastric glands, pancreas and intestine in response to various stimuli; motor (evacuation and peristalsis) activity of the stomach and intestine, using mechanographic recording and roentgenologic studies. A number of general factors was also determined: changes in body weight in all the dogs, in some dogs the morphologic blood picture, blood sugar and absorption and assimilation of certain substances.

Once the mean normal values had been determined, gastric resection (usually 2/3, in some dogs 4/5) was performed by the Billroth II method as modified by Hofmeister-Finsterer. Two to three weeks postoperatively the same determinations were carried out systematically. The maximal period of follow-up after gastric resection was 2 years.

EXPERIMENTAL RESULTS

The dogs were divided into 3 groups in accordance with their general condition following extensive gastric resection:

Group I – dogs who showed rapid restoration or stabilization of body weight, normal food excitability, absence of signs of disorders of intestinal function, vomiting, etc. This group included 5 dogs.

Group II – dogs who showed periodic loss of weight or prolonged underweight state, periodic disturbances of digestive activity, impairment of food excitability, i. e. signs of partial compensation of the disrupted functions. This group included 12 dogs.

Group III – dogs (5) who died during a period of 1 year (after 5-7-9 months) with progressive loss of weight, cachexia, manifestations of disturbances of intestinal function, anemia. These animals showed marked disturbances of food excitability.

Thus, despite the fact that the given method of operation causes sharp impairment of the digestive function as the result of dropping out of normal gastric function and normal action of pancreatic juice and bile on food, the organism can in the majority of cases mobilize compensatory mechanisms, correcting abnormal conditions created by the operation.

The question arises whether it can be supposed that compensation occurs by virtue of the remaining part of the stomach (part of the fundus and cardia)?

It must be noted that the overwhelming majority of clinical investigations of the contents of the stomach stump show the presence of persistent, prolonged achylia or hypofunction of the gastric glands in patients who had sustained resection of two-thirds of the stomach.

Some experimental data, as well as investigations carried out in our laboratory, confirm the presence of prolonged hyposecretion by the gastric glands after a similar operation in dogs. Moreover, roentgenologic observations on 7 dogs (up to 2 years postoperatively) and autopsies on 5 dogs long after the operation (from 6 to 12 months) showed no appreciable enlargement of the stomach stump. These facts indicate that the stomach stump cannot play an important part in the compensatory process.

Evidently, the compensatory morphologic rearrangement and regeneration of the affected stomach is only possible in cases where only separate parts of the stomach had been removed (Lazovskii, Sharovatova and Kogan, 1939) but not such an extensive portion as was the case in our investigations.

To what extent does the pancreas participate in the process of compensation?

According to the data of I. V. Malkiman and E. A. Pechatnikova, obtained in experiments on dogs with exteriorized pancreatic duct, there is considerable and prolonged lowering of external secretion function of the gland in response to bread and meat. Several months after the operation there is sometimes a tendency to restoration of function followed by another sharp decrease. There is also a substantial change in the total amount of enzymes in the pancreatic juice.*

* See I. V. Malkiman's paper in the same issue.

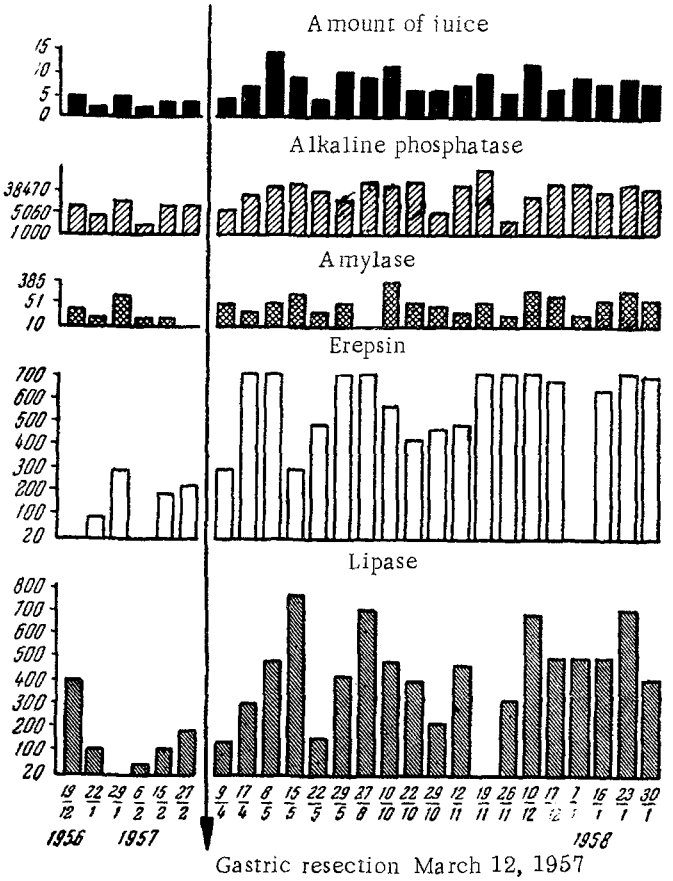

Fig. 1. Secretory function of the small intestine before and after gastric resection in the dog Sulak. Stimulus – irrigation with peptone solution. Enzyme activity is expressed in conventional units.

The work of some foreign authors (Richman, 1954; Annis, Hallenbeck, 1952) also attests to a sharp drop in the secretory activity of the pancreas in dogs following resection of the distal part of the stomach.

These data indicate that the pancreas also cannot play an important role in the compensatory rearrangement of the activity of the digestive system after extensive gastric resection.

Unlike the secretory function of the stomach and the pancreas, the secretory activity of the small intestine after gastric resection is, according to our data, not only not depressed but in most cases enhanced.

Comparison of "periodic" intestinal secretion with secretion obtained in response to mechanical stimulation and to a chemical stimulus (irrigation of the intestine with peptone solution) showed that increased secretion was more marked in response to the chemical stimulus.

Enhancement of enzyme-secreting function is particularly noticeable.*

Increased concentration and total amount of enzymes were observed beginning with the 1st-2nd month after operation and persisted, sometimes with some fluctuations, throughout the period of investigations (up to $1\frac{1}{2}$ years after gastric resection). Particularly marked was the secretion of enzymes participating in protein breakdown, and in isolated cases of amylase and lipase also (Fig. 1).

With respect to the dynamics of changes in the motor-evacuation activity of the digestive tract following

* The following enzymes were determined: enterokinase, alkaline phosphatase, amylase, lipase, erepsin; the methods used were those developed or modified in G. K. Shlygin's laboratory (Shlygin, 1950; Fomina, Mikhlin and Shlygin, 1952).

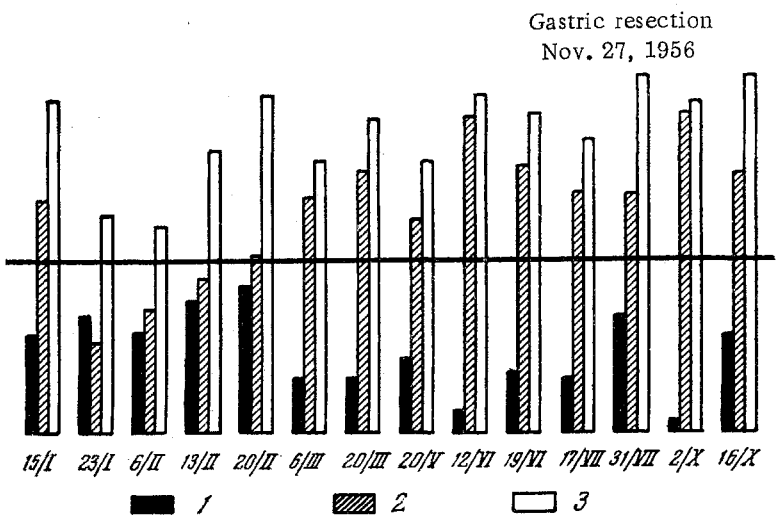

Fig. 2. Evacuation function of the stomach and small intestine after gastric resection in the dog Belianka.
1) Time over which the milk mixture remained in the stomach; 2) time during which the milk mixture remained in the small intestine; 3) total time.

gastric resection, the experiments showed that as a rule there was disturbance of periodic "fasting" motor activity of the small intestine expressed in increased periods of work or even continuous contractions. Restoration of periodicity was observed after an average of 2-3 months.

Starting roughly about the same time, some dogs began to show, as demonstrated by roentgenologic examination of gastric and intestinal evacuation, slowing down of the passage of food along the small intestine. The slowing down increased gradually and reached a maximum a long time after operation (6-12 months). It is interesting to note that this slowing down is more pronounced when food is evacuated from the stomach stump more quickly (Fig. 2). There is a simultaneous slowing down of peristalsis in the small intestine.

The appearance of the features described above a long time after the operation suggests that these processes are associated with morphologic rearrangement of the digestive tract.

The compensatory character of increased secretory function of the small intestine and change in the transport of food is indicated by the fact that the degree and effectivity of these phenomena following on gastric resection are closely connected with the dynamics of change in some general indices of the dog's condition, in particular body weight.

The first results of the work thus showed that compensation of impaired digestive function in this case occurred by virtue of rearrangement of the secretory-motor activity of the small intestine. Further investigations were devoted to the question of the mechanisms and means of achievement of compensatory reactions.

With this aim in view, experiments were performed on dogs with fistulas of two isolated segments of the small intestine. In one of the segments the neurovascular connection with the mesentery was preserved; in the second segment the innervation was interrupted. The experiments showed that there was increased secretion in the innervated intestinal segment postoperatively whereas in the denervated segment such increase was either absent or was only very slight (Fig. 3). These facts speak of the significance of extramural nervous pathways in the compensatory-adaptational reaction of the digestive system.

It is interesting that increased secretory function of the small intestine was most marked when products of food digestion (peptone) were used as stimuli. It may be supposed that one of the quickly mobilized compensatory mechanisms may be a change in the sensitivity of small intestine receptors consequent on changes in the physicochemical properties of food (chyme) which gains access to the small intestine following gastric resection, with resulting rearrangement of unconditioned reflex activity. In the light of the work of V. N. Chernigovskii and V. A. Lebedeva (1947-1951) on the mechanisms of intestinal chemoreception, such a hypothesis is quite

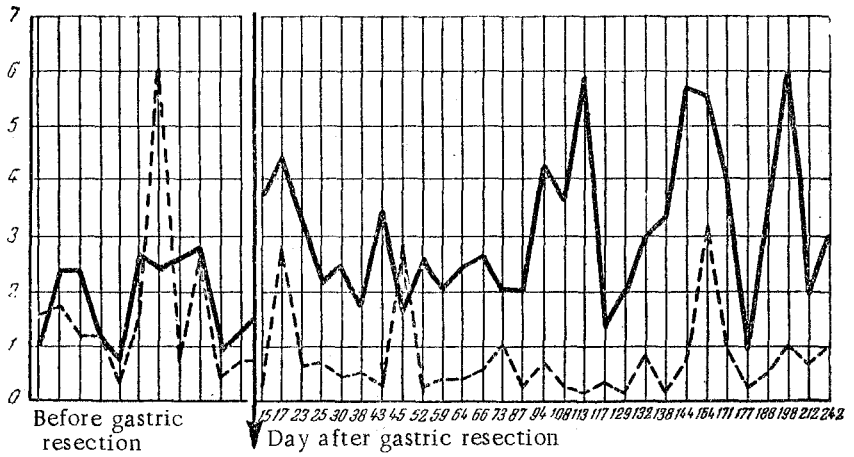

Fig. 3. Secretion of juice on mechanical stimulation of isolated segments of the small intestine in the dog Belianka.
——— secretion from the innervated segment, ------ secretion from the denervated segment.

feasible. Our next problem is that of studying the role of the properties of chyme in the effectiveness of the observed compensatory reactions.

It must also be emphasized that the state of the food center also plays a very important part in the course of the compensatory process, in some cases this role being decisive. The majority of our experimental dogs showed, after gastric resection, various degrees of food excitability, especially the group III dogs who died several months postoperatively. The next problem in this connection is elucidation of the causes and mechanisms responsible for the disturbances of the functional state of the food center under these conditions.

According to preliminary data, these disturbances are connected both with the exclusion of so vast a receptor area as the gastric mucosa and with impairment of absorption from the digestive tract with consequent changes in blood chemistry.

The results reported are a confirmation and further development of the theoretical views of I. P. Razenkov who has always stressed the significance of the initial functional state of the digestive organs and their higher regulatory mechanisms in the reactivity of the digestive tract.

SUMMARY

This article presents results of examination of the compensatory processes and the function of the digestive system after partial (two-thirds and four-fifths) resection of the stomach in dogs. These data were obtained in experiments on 28 dogs, observed up to 2 years after the operation. The secretory function and the enzyme secretion of the stomach, pancreas and small intestine, as well as the motor function and absorptive property of the small intestine, were studied.

The experiments demonstrated that compensation of the functions of the digestive system took place mainly by way of rearrangement of the secretory motor function of the small intestine. Certain data concerning the mechanisms of compensatory reactions were also obtained.

The role of the extramural intestinal innervation and the functional condition of the food center in compensatory processes was studied in particular.

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