CHANGES IN CONTACT DIGESTION IN THE SMALL INTESTINE OF RATS AFTER WHOLE-BODY X-RAY IRRADIATION

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After whole-body irradiation of rats with x rays (550 and 1200 R) profound disturbances of contact hydrolysis of sucrose and of enzyme formation were found in the epithelial cells of the small intestine. The distal portions of the small intestine were more resistant to x rays than the proximal. In the recovery period the functional activity of the distal portion of the small intestine was stimulated.

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Several investigators [1, 5] have established the character of radiation disturbances of contact digestion, but their investigations have dealt entirely with the proximal portion of the jejunum. However, we know that different parts of the small intestine participate to different degrees in the process of digestion [2, 3, 6, 8-10]. A proximo-distal gradient of distribution of enzymes has been found in the small intestine of mammals, as a result of which the intensity of hydrolysis and absorption of food substances falls toward the aboral end. Evidence has been obtained of differences in the vulnerability of different parts of the small intenstine to radiation [7, 11], and also of differences in the degree of disturbances of contact hydrolysis of disaccharides in lead poisoning [4].

In face of these facts, the present investigation was carried out to study the character of disturbances of contact hydrolysis of sucrose and of enzyme formation in the proximal and distal portions of the small intestine of rats at various periods of acute radiation sickness.

EXPERIMENTAL METHOD

Experiments were carried out on 175 noninbred albino female rats weighing 160-200 g, 80 of which were used as controls. The animals were sacrificed by suffocation and the whole of the small intestine was removed and washed with 15 ml cold Ringer's solution. Two segments were then removed from the jejunum and ileum, situated 20 cm from the pylorus and 15 cm from the ileocecal angle respectively. The contact hydrolysis of sucrose in these segments was investigated by A. M. Ugolev's (1960) method, using invertase activity on the surface of the intestinal mucosa as index. The total invertase reserve in the intestinal cells was also studied (from the activity of a homogenate). Invertase activity was judged from the amount of reducing sugars formed, determined by A. M. Ugolev's modification of Nelson's method. The conditions of irradiation were: voltage 185 kV, current 17 mA, filters 0.5 mm Cu and 1 mm Al, skin-focus distance 40 cm, dose rate 58-62 R/min.

EXPERIMENTAL RESULTS

In the experiments of series I the animals were irradiated in a dose of 550 R ($JD_{40/30}$). At intervals of 1, 3, 5, 7, 10, 15, and 30 days after irradiation, 10 rats were sacrificed. The results of this series of experiments are given in Fig. 1, showing that on the second day after irradiation no statistically significant changes in contact hydrolysis of sucrose were observed in the proximal and distal portions of the small intestine. Meanwhile the enzyme-forming power of both parts of the intestine was reduced ($P < 0.01$). On the third day after irradiation all the investigated indices were significantly lowered. However, the degree of the decrease in invertase activity on the surface of the mucosa of the distal portion of the intestine was less marked than in the proximal. Whereas in the proximal portion the activity was only 22.7% of the control level, in the distal portion it was 39.7%. In both parts activity of the homogenate was lowered by 75-80% ($P < 0.001$). Recovery of the disturbed intestinal functions began to take place 5-7 days after irradiation.

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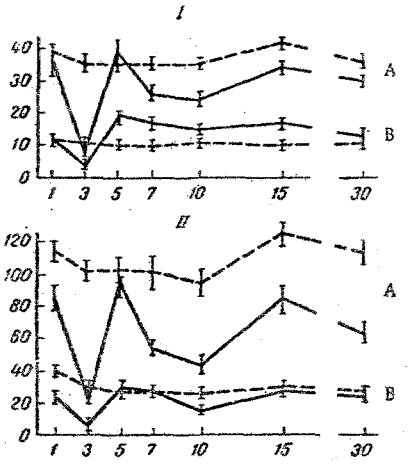

Fig. 1. Effect of irradiation in a dose of 550 R on contact hydrolysis of sucrose and enzyme formation in the small intestine. I) Activity on surface of mucosa; II) activity of homogenate. Abscissa, times after irradiation (in days); ordinate, quantity of reducing sugars (in mg%). A) Proximal portion; B) distal portion; dotted lines represent control, continuous lines represent experiment.

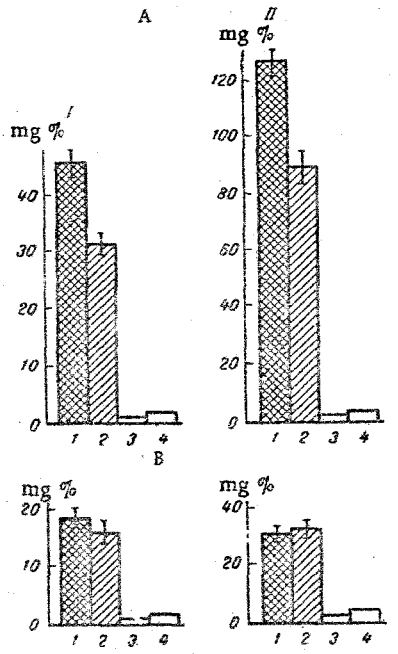

Fig. 2. Effect of irradiation in a dose of 1200 R on contact hydrolysis of sucrose and enzyme formation in the small intestine. I) Invertase activity on surface of mucosa; II) in homogenate; A) proximal portion, B) distal; 1) control, 2) one day, 3) 3 days, 4) 5 days after irradiation.

The degree of recovery of function differed in the two portions of the intestine. In the proximal portion of the jejunum invertase activity on the surface of the mucosa returned to its initial level, but in the distal portion of the ileum it exceeded the control value by 81% ($P < 0.001$). The enzyme-forming power of the intestinal epithelial cells returned to its initial level in both parts of the intestine. Normalization of the investigated indices in the proximal portion of the jejunum was temporary, and was followed by a persistent decrease lasting one month after irradiation. This secondary wave of decrease of enzyme-forming power of the intestine was particularly marked (Fig. 1). Similar changes were observed previously in our laboratory [1]. So far as the distal portion of the ileum is concerned, contact hydrolysis of sucrose was maintained at a higher level than in the control animals throughout the period of observation. The total reserves of the enzyme in the intestinal wall were lower than in the controls, although to a lesser degree than in the proximal portion of the jejunum.

In the experiments of series II the animals were irradiated in a dose of 1200 R. These animals developed an intestinal form of acute radiation sickness [12], terminating in death of all the animals 4-5 days after irradiation. The results of this series of experiments were illustrated in Fig. 2. By the second day after irradiation marked changes in contact hydrolysis of sucrose were observed in the proximal portion of the jejunum ($P < 0.001$). In the distal portions of the intestine no statistically significant changes in these indices were found 24 h after irradiation. All these indices were practically equal to zero 3 days after irradiation. Only 5 rats could be investigated 5 days after irradiation, but no sign of recovery of the studied intestinal functions was observed in them.

Hence, after irradiation of the animals in a dose of 1200 R, disturbances of contact hydrolysis of different degrees were observed in the proximal and distal portions of the small intestine 24 h after irradiation only; for 3 days after irradiation contact digestion was completely abolished and had not recovered by the time that the animals died.

These results indicate severe disturbances of contact hydrolysis of sucrose and of enzyme-forming processes in the epithelial cells of the small intestine after whole-body x-ray irradiation, these disturbances reaching a maximum three day after irradiation, i.e., at a time when, as various workers have shown, the radiation injury in the morphological picture of the epithelium of the villi reaches a maximum. However, the processes of enzyme formation and contact hydrolysis undergo more profound changes than the structural elements of the intestinal mucosa. According to some data, obtained with the optical microscope, 48-72 h after irradiation of mice in a dose of 550 R only hypochromia of the nuclei with pycnotic changes in some places are observed [11], whereas the indices of intestinal epithelial function which we investigated were considerably lowered. It was also found that enzyme-forming processes were more labile than contact hydrolysis. Enzyme formation was disturbed sooner and for a longer period. Finally, differences were found in the degree of radiation injury to contact hydrolysis of sucrose in the proximal and distal portions of the small intestine. The distal portions were more resistant to the action of ionizing radiation. Radiation injury to different parts of the small intestine of a similar character have been observed in the histological picture [7, 11], and also in relation to activity of acid and alkaline phosphatase and pseudocholinesterase, and the electrolyte composition of the intestinal mucosa [7]. During the period of recovery of the disturbed intestinal function the distal portions show increased functional activity, which may be regarded as a compensatory, adaptive response of the body.

LITERATURE CITED

1. R. I. Gavrilov and V. Yu. Domanskii, Radiobiologiya, No. 3, 394 (1966).
2. P. Dei Lei and N. N. Iezuitova, Dokl. Akad. Nauk SSSR, 146, No. 3, 731 (1962).
3. N. N. Iezuitova, N. M. Timofeeva, O. K. Koldovskii, et al., Dokl. Akad. Nauk SSSR, 154, No. 4, 990 (1964).
4. T. Ya. Nadirova, in: Physiology and Pathology of Digestion [in Russian], L'vov (1965), p. 192.
5. A. M. Ugolev, N. N. Iezuitova, T. Ya. Nadirova, et al., Dokl. Akad. Nauk SSSR, 166, No. 2, 472 (1966).
6. W. C. Alvarez, Am. J. Physiol., 35, 177 (1914).
7. D. G. Baker and R. I. Mitchell, Gastroenterology, 44, 291 (1963).
8. D. G. R. Blair and J. Tuba, Canad. J. Biochem., 41, 905 (1963).
9. A. Dahlqvist and D. L. Thomson, J. Physiol. (London), 167, 193 (1963).
10. Lanois and R. Lepine, Arch. Physiol. Norm. Path. (Paris), 1, Ser. 3, 92 (1883).
11. W. Montagna and J. W. Wilson, J. Nat. Cancer Inst., 15, 1703 (1955).
12. H. Quatler, E. F. Lanze, M. E. Keller, et al., Am. J. Physiol., 15, 1703 (1951).