ULTRASTRUCTURE OF THE DUODENAL MUCOSA OF RATS UNDER STRESS

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The duodenal mucosa of rats was studied electron-microscopically after exposure to stress (immobilization on a special frame) for 24 h. Moderately severe changes were found in the enterocytes, manifested chiefly as focal destruction of the mitochondrial cristae and an increased number of lysosomes. The results correlate with results of histochemical investigations of the same object published previously. Changes are also described in the goblet cells and blood vessels.

KEY WORDS: duodenum; stress; changes in organelles.

The pathogenesis of acute ulcerative lesions of the gastrointestinal tract is being intensively studied at the present time [1, 3-7] and particular attention is being paid to the mucous membrane of the stomach, where acute ulcerative lesions are manifested most clearly under stress. Changes in the duodenal mucosa under stress very rarely reach the degree of erosion, but they are usually manifested as hyperemia, edema, increased round-cell infiltration of all layers of the mucosa, and various types of disturbance of tissue metabolism [2].

In order to search for subcellular equivalents of these metabolic disturbances an electron-microscopic study was made of the duodenal mucosa of rats under stress induced by immobilization. This model of stress was used in preference to others because it gives rise to acute ulcerative defects in the mucous membrane of the stomach much more often than other types of stress [3].

EXPERIMENTAL METHOD

Nine male Wistar rats weighing 150-200 g were used. Five rats were exposed to stress by fixing them to a special frame for 24 h [10] and four intact rats acted as the control. At the end of exposure the control and experimental rats were decapitated simultaneously. Pieces of the duodenal wall taken from the proximal part of the organ were fixed in 3% glutaraldehyde solution in 0.1 M buffer (pH 7.4) for 2.5 h, then rinsed in buffer with the addition of 6.8% sucrose solution and postfixed for 2 h in a 1% buffered solution of OsO_4. After dehydration in alcohols of increasing strength, with the addition of uranyl acetate and absolute acetone, the tissue was embedded in a mixture of Epon and Araldite [8]. In every case before the final sharpening of the pyramids a section was cut from each block, 1 μ in thickness, stained with methylene blue, and examined in the light microscope to provide precise orientation in the specimen. Ultrathin sections obtained on the LKB-III ultratome were counterstained with lead [9] and examined and photographed in the HU-IIEs electron microscope.

EXPERIMENTAL RESULTS

In many mitochondria in enterocytes of the experimental animals focal destruction of the cristae was observed, usually accompanied by increased translucency in these areas of the matrix (Fig. 1a). Other mitochondria and even other areas of the changed mitochondria were free from defects and there was no change in the size of their organelles. The number of lysosomes and lysosome-like bodies on the whole was increased; myelin figures were more frequently seen than in the control. The profiles of the granular endoplasmic retic-

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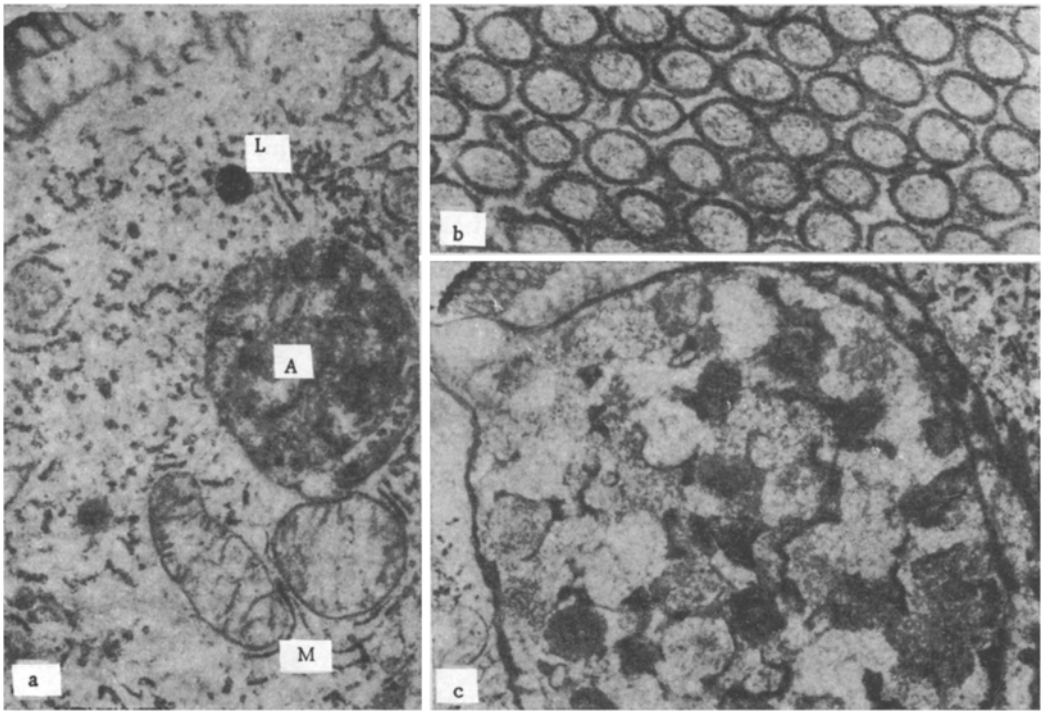

Fig. 1. Enterocytes and goblet cell of rat with induced stress: a) focal destruction of mitochondrial cristae of enterocytes (17,000 ×); b) transverse section through microvilli of brush border of enterocyte, intact double plasma membrane (58,000 ×); c) heterogeneity of drop of secretion of goblet cell at apex of villus (12,200 ×). M) Mitochondrion; A) autophagolysosome; L) lysosome-like bodies.

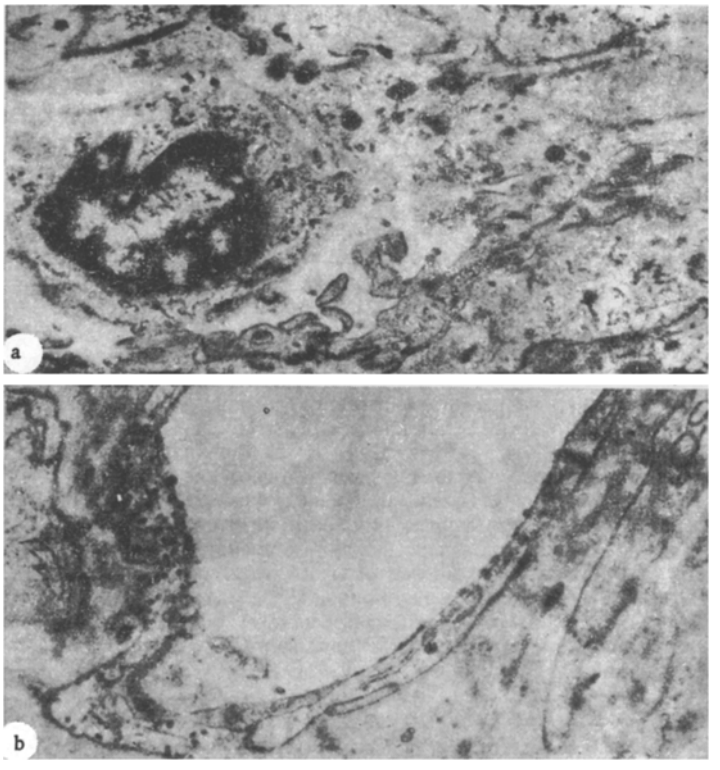

Fig. 2. Different states of capillaries of duodenal mucosa of rat with induced stress: a) lumen constricted by swelling of endothelium; b) lumen dilated, endothelium flattened (12,200 ×).

ulum were less frequently seen, whereas the number of ribosomes united to form polysomes was increased inconstantly. It must be emphasized that all the changes observed were on the whole not severe and they were frequently mosaic in character. The microvilli of the brush border were completely preserved and in transverse sections their membranes were clearly double in outline (Fig. 1b). The terminal network, the other organoids, and the cell nuclei of the experimental animals likewise were indistinguishable from the controls.

In goblet cells located at the apices of the villi drops of secretion were often distinguished by uneven density (Fig. 1c), which was rarely seen in the control animals.

The number of endocrine cells of different types and of eosinophils was inconstant and varied from animal to animal and from block to block.

The picture of the mucosal blood vessels was highly polymorphic. Besides capillaries with the usual appearance other vessels were seen with flattened endothelium and a wide lumen or, by contrast, with a constricted lumen as the result of swelling of the endothelium, accompanied by the formation of numerous microprojections (Fig. 2). The number of pinocytotic vesicles varied considerably.

The model of stress used in this investigation was thus accompanied by several ultrastructural changes in the duodenal mucosa, especially by injury to mitochondria. It is important to stress that these changes in the mitochondria did not include swelling, and they were found in cells which satisfied the criteria of good fixation.

These results agree with those obtained by Evdokimov [2] who found, by a cytospectrophotometric method, a decrease in oxidoreductase activity of the enterocytes in stress induced by immobilization.

The variation in density of the droplets of secretion of the goblet cells may be evidence of variation in their maturation and also that when discharged into the lumen of the intestine not all the drops of secretion have reached the necessary degree of maturity. The possibility cannot be ruled out that this is the morphological reflection of an accelerated life cycle of the goblet cells.

Within the limits of this investigation it is impossible to say with confidence what are the causes of the changes observed in the duodenal mucosa. However, the inequality in the filling of the vessels with blood and the generally varied state of the vessels, in conjunction with the predominant damage to the mitochondria, suggest that hemodynamic disturbances play an important role in the genesis of these changes, more especially because the role of such disturbances has been demonstrated by the study of lesions of the gastric mucosa in the same type of stress [5-7].

Meanwhile the changes in the duodenum were much less severe than in the stomach. There were no erosions, ulcers, or other gross defects, the morphological changes observed were on the whole small, they were found only at the ultrastructural level, and they were not total in character in the specimens examined. The concrete mechanisms of the greater resistance of the duodenal mucosa than of the gastric to stress must await further investigations for their elucidation.

LITERATURE CITED

1. O. N. Zabrodin, "Destructive lesions induced in the stomach wall by electrical stimulation of immobilized rats and the action of neurotropic agents on their development," Author's Abstract of Candidate's Dissertation, Leningrad (1965).
2. V. V. Evdokimov, Abstracts of Proceedings of a Conference of Junior Scientists of the No. 4 Chief Administrative Division, Ministry of Health of the USSR [in Russian], Moscow (1974), pp. 53-55.
3. D. A. Brodie and H. M. Hanson, Gastroenterology, 38, 353 (1960).
4. D. A. Brodie, J. Neuropsychiat., 4, 388 (1963).
5. H. Goldman and C. B. Rosoff, Am. J. Path., 52, 227 (1968).
6. T. Hase and B. J. Moss, Gastroenterology, 65, 224 (1973).
7. D. A. Krisst and S. J. Freimark, Am. J. Path., 73, 411 (1973).
8. H. H. Mollenhauer, Stain Technol., 39, 111 (1964).
9. E. S. Reynolds, J. Cell Biol., 17, 208 (1963).
10. H. Selye, Brit. J. Exp. Path., 17, 234 (1936).