5. A. A. Pokrovskii and K. A. Korovnikov, in: Problems in Medical Chemistry [in Russian], Moscow (1973), pp. 5-36.
6. G. S. Yakobson, Z. Ya. Gizatulin, Yu. P. Shorin, et al., Farmakol. i Toksikol., No. 3, 349 (1975).
7. K. Hirotani, Folia Endocrinol. Jap., 45, 954 (1969).
8. H. U. Bergmeyer, Methoden der enzymatischen Analyse, Vol. 1, Berlin (1970), pp. 438-439.
9. J. A. Castro, M. I. Diaz Gomez, E. C. de Ferreyra, et al., Biochem. Biophys. Res. Commun., 47, 315 (1972).
10. H. Holzer, E. Holzer, and G. Schulz, Biochem. Z., 326, 385 (1955).
11. M. T. Jones and M. A. Stockham, J. Physiol. (London), 184, 741 (1966).
12. D. Mattingly, J. Clin. Path., 15, 374 (1962).
13. K. W. McKerns, Canad. J. Biochem., 43, 923 (1965).
14. C. P. W. Tsang and F. Peron, Steroids, 16, 41 (1970).
15. D. Rudack, E. M. Chisholm, and D. Holten, J. Biol. Chem., 246, 1249 (1971).

# GLUCOSE TRANSPORT IN THE SMALL INTESTINE AFTER LIGATION OF THE BILIARY-PANCREATIC DUCT IN RATS

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Muco-serosal glucose transport along and against the concentration gradient (the modified "everted sac" method) was determined in six segments of small intestine of rats on the 4th, 7th, 14th and 28th days after ligation of the combined biliary-pancreatic duct. The dynamics of modification to the transport systems in each segment of the intestine differed according to their dependence on the sources of energy. In the early period after the operation transport along the concentration gradient was mainly intensified, but in the later stages transport against this gradient was intensified.

KEY WORDS: small intestine; glucose transport; ligation of biliary-pancreatic duct.

Adaptive and compensatory reactions in different physiological systems evidently obey certain general rules [5, 7, 10]. Attempts have recently been made to extend ideas regarding methods of regulation to the metabolic level [1, 2]. These views must be taken into consideration when adaptations in systems of membrane hydrolysis and transport are studied, for the metabolic properties of the enterocytes vary along the course of the small intestine [3, 8, 11]. Glucose transport in enterocytes is known to take place by several mechanisms [6, 12, 13]. With different dietary intakes the properties of the transport system may vary differently along (TCG) or against (TACG) the concentration gradients. No comparison between these two systems of transport under pathological conditions has been carried out until recently. Ugolev [8] has postulated that against the background of adaptive and compensatory structural changes in the small intestine the properties of transport systems characterized by unequal dependence on sources of energy may vary differently.

In this investigation this problem was studied in relation to glucose by comparing TCG and TACG in all parts of the small intestine of rats after ligation of the biliary-pancreatic duct.

## EXPERIMENTAL METHOD

Experiments were carried out on 25 adult albino rats kept on a mixed diet and starved for 18 h before being used. The rats were decapitated on the 4th-28th day after ligation of the biliary-pancreatic duct; the small intestine (without the duodenum) was removed and divided into six equal segments. Muco-serosal glucose transport was studied by a modified "everted sac" method [4, 12]. Two lengths (about 5 cm) were iso-

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TABLE 1. Muco-Serosal Glucose Transport by Different Segments of Rat Small Intestine after Ligation of Biliary-Pancreatic Duct (incubation in 11.1 mM glucose solution for 30 min n = 5, M ± m)

| Day after operation | Segments of small intestine | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | | II | | III | | IV | | V | | VI | |
| | A | B | A | B | A | B | A | B | A | B | A | B |
| **Transport along concentration gradient** | | | | | | | | | | | | |
| Control | 8,8±0,9 | 100 | 9,1±1,5 | 100 | 11,1±1,2 | 100 | 8,5±1,0 | 100 | 6,8±0,9 | 100 | 4,0±0,8 | 100 |
| 4-th | 12,3±2,0 | 139 | 12,2±1,9 | 133 | 11,9±2,1 | 107 | 10,8±1,8 | 127 | 8,5±0,7 | 124 | 3,9±0,8 | 97 |
| 7-th | 16,1±2,6* | 183 | 16,6±2,4* | 181 | 11,9±2,2 | 107 | 15,5±2,1* | 182 | 9,1±1,3 | 133 | 3,6±0,3 | 89 |
| 14-th | 11,7±2,2 | 133 | 12,2±1,5 | 133 | 14,4±1,3 | 130 | 18,0±2,3* | 211 | 11,9±2,0* | 174 | 3,3±0,3 | 82 |
| 28-th | 8,1±0,2 | 92 | 7,3±1,2 | 79 | 10,3±1,1 | 93 | 12,0±1,9 | 140 | 10,0±2,4 | 146 | 4,3±1,5 | 107 |
| **Transport against concentration gradient** | | | | | | | | | | | | |
| Control | 16,6±1,5 | 100 | 15,2±1,9 | 100 | 16,0±2,8 | 100 | 15,9±2,1 | 100 | 16,4±1,3 | 100 | 11,3±1,2 | 100 |
| 4-th | 17,1±0,6 | 105 | 17,1±1,0 | 115 | 17,3±1,2 | 107 | 17,2±1,3 | 107 | 17,2±0,6 | 104 | 13,6±0,5 | 120 |
| 7-th | 24,7±2,2* | 148 | 23,4±2,3* | 154 | 20,8±1,3 | 131 | 26,1±3,0* | 164 | 21,1±1,9 | 128 | 13,1±0,9 | 117 |
| 14-th | 22,2±1,4 | 134 | 23,4±2,1* | 154 | 24,6±2,5* | 154 | 24,4±1,6* | 153 | 18,0±1,1 | 110 | 13,0±0,3 | 116 |
| 28-th | 17,8±1,3 | 107 | 20,9±2,2 | 138 | 22,6±1,2* | 142 | 26,0±2,3* | 163 | 20,1±0,8* | 125 | 15,6±1,3* | 136 |

Legend. 1. A) Level of transport in mM; B) Level of transport in % of control. 2) Values differing significantly from control ($P < 0.05$) marked by asterisk.

lated from each segment; the first length was used to determine TCG, the second to determine TACG. The lengths of intestine were incubated in 25 ml of glucose saline (11.1 mM). To determine TCG, the internal cavity of the length of intestine (serosal surface) was filled with Ringer's solution, but to determine TACG it was filled with glucose saline solution. Incubation continued for 30 min at 37°C with constant aeration. At the end of incubation the concentration of reducing sugars was determined in the liquid bathing the aerosal surface by a modified Nelson's method [9]. Transport activity in rats with an intact external secretion of pancreatic juice and bile (control) was determined on the fourth day after laparotomy.

## EXPERIMENTAL RESULTS

After disturbance of the excretion of pancreatic juice and bile the glucose transport systems were altered and the dynamics of the change in TCG and TACG differed in each segment of the intestine (Table 1). The rate of onset of the changes and their intensity in the early periods after the operation were as a rule much greater for TCG than for TACG. The exception was segment III, in which TCG was almost unchanged during the first week of observation, and segment VI, where there was a tendency for TCG to be slowed. In the later periods of observation, on the other hand, TACG increased compared with the control by a greater degree than TCG. The exception in this case was segment V, where the increase in active glucose transport was not significant. However, even in this part of the intestine, TCG was slowed (by almost 30%) between the 14th and 28th days, whereas TACG showed a tendency to take place a little faster.

In this pathology the temporal dynamics of structural changes in the two glucose transport systems characterized by low and high dependence respectively on metabolic energy is different. The relationship between the reactions of these two systems differed in different segments of the intestine, indicating that these reactions may be dependent upon the properties of the enterocyte populations.

## LITERATURE CITED


1. A. Laborit, Regulation of Metabolic Processes [Russian translation], Moscow (1970).
2. A. Laborit, Metabolic and Pharmacological Bases of Neurophysiology [Russian translation], Moscow (1974).
3. N. N. Lebedev, in: The Physiology of Man and Animals. Digestion [in Russian], Vol. 13, Moscow (1974), pp. 5-67.
4. G. I. Loginov and A. M. Ugolev, in: Proceedings of the 4th Inter-Institute Scientific Conference of Physiologists and Morphologists of Pedagogic Institutes to Commemorate the 120th Anniversary of the Birth of I. P. Pavlov [in Russian], Yaroslavl' (1970), pp. 231-233.
5. J. H. Milsum, Biological Control Systems Analysis, McGraw Hill, New York, (1966).
6. N. N. Nikol'skii, in: Textbook of Physiology. The Physiology of Digestion [in Russian], Leningrad (1974), pp. 7-26.

7. V. V. Parin and R. M. Baevskii, Introduction to Medical Cybernetics [in Russian], Moscow (1966).
8. A. M. Ugolev, Contact Digestion [in Russian], Leningrad (1972).
9. A. M. Ugolev and N. N. Iezuitova, in: Investigation of the Digestive Apparatus in Man [in Russian], Leningrad (1969), p. 192.
10. V. I. Shumakov, V. N. Novosel'tsev, et al., Stimulation of the Physiological Systems of the Organism [in Russian], Moscow (1971).
11. E. Weser and B. Hernandez, Gastroenterology, 60, 69 (1971).
12. T. H. Wilson, Intestinal Absorption, Saunders, Philadelphia (1962).
13. G. Wiseman, Absorption from the Intestine, Academic Press, New York (1964).

# REGIONAL REDISTRIBUTION OF BLOOD IN UNANESTHETIZED RATS AFTER BLOOD LOSS

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Relative changes in local blood volume in 46 vascular regions of the body after moderate and severe blood loss are described. Moderate blood loss caused a redistribution of blood from the skin of the chest and hind limbs, most organs of the abdomen and pelvis, the muscular and bony tissues of the abdomen, pelvis, and limbs to the brain, heart, lungs, kidneys, stomach and to the muscles of the head and neck. After severe blood loss the changes were similar but the blood volume in the kidneys and stomach was reduced; a relative increase in the blood volume in the muscular and bony tissues of the thorax also was observed. The intensity of the redistributive response to severe blood loss was less than to a moderate blood loss.

KEY WORDS: regional redistribution of blood; intravascular blood reserve; blood loss.

Changes in the general and regional circulation play an important role after blood loss [5, 6, 9]. Fluctuations in regional blood volume are determined mainly by changes in the lumen of the capacitive levels and they reflect the functioning of the dynamic intravascular blood reserve [3, 7, 10, 12]. To detect mobilization of the intravascular blood reserve it is clearly necessary to record changes in the relative blood volume in many different parts of the vascular system simultaneously. The response will be manifested more clearly if the mechanisms of regulation of the circulation are unchanged by anesthesia or by forcible fixation.

The regional redistribution of blood after blood loss was studied in this investigation with allowance made for the demands mentioned above.

## EXPERIMENTAL METHOD

Four days before the experiments were carried out on male rats weighing 190-240 g, a polyethylene catheter was inserted into their external jugular vein and its end was brought out onto the head. Twice a day the catheter was washed out with physiological saline containing heparin so that at the beginning of the experiment the animals were accustomed to the manipulations; food was taken away from the cages for 18-20 h before the experiment. Blood was taken from an incision in the tail in a volume equivalent to 18.0 ± 1.82% of the total circulating blood volume (CBV) over a period of 5-7 min (moderate blood loss) or to 38.1 ±1.91% of the CBV over a period of 7-12 min (severe blood loss). A mixture of red blood cells tagged with $^{51}Cr$ and of albumin-$^{131}I$ was injected through the catheter 20 min after bleeding and, after they had become uniformly mixed

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