SOME PRINCIPLES GOVERNING ABSORPTION OF SUGAR FROM THE SMALL INTESTINE

(UDC 612.332.72 : 612.15)

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 61, No. 1, pp. 28-32, January, 1966
Original article submitted July 13, 1964

Many studies have been made of the absorption of sugars from the small intestine. Initially great importance was attached to the physicochemical laws of osmosis and diffusion, the concentration gradient, the oncotic pressure of the blood, the hydrostatic pressure in the lumen of the intestine, and so on [11, 12]. It was subsequently shown, however, that the absorption of sugars is an active biological process maintaining the activity of the epithelial cells of the small intestine with the participation of enzyme systems and of biological processes of phosphorylation and dephosphorylation of the sugars in the intestinal wall, and also the activity of the intestinal villi, and so on [1, 16, 17].

Nevertheless we have little information on the interconnection and interdependence of the circulatory processes and absorption. Particularly few investigations have been made of the role of the regional circulation in absorption from the small intestine. This may largely be explained by the inadequacy of methods used to detect changes in the regional circulation and the volume blood flow in the regional vessels in the period of absorption. Only isolated studies have been made of this problem. For example, when the circulation of the blood was impaired by ligation of some of the mesenteric vessels, Borchardt [4] observed a marked decrease in the absorptive activity.

The regulatory influence of potassium and calcium salts and also of various hormones on the absorption of sugar from the small intestine has been established in frogs [8-10]. Atkinson and co-workers [3] observed a decrease in the absorption of sugar in cases of circulatory insufficiency.

No reports of investigations of the absorption of sugars from the intestine and its relationship to the volume blood flow and in the presence of different blood volumes could be discovered. There is no doubt about the im-

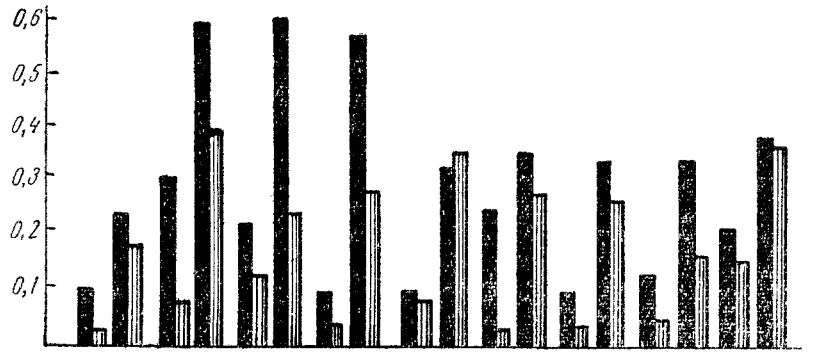

Fig. 1. Relationship between absorption of sugar and volume blood flow in regional vessels. For explanation, see text.

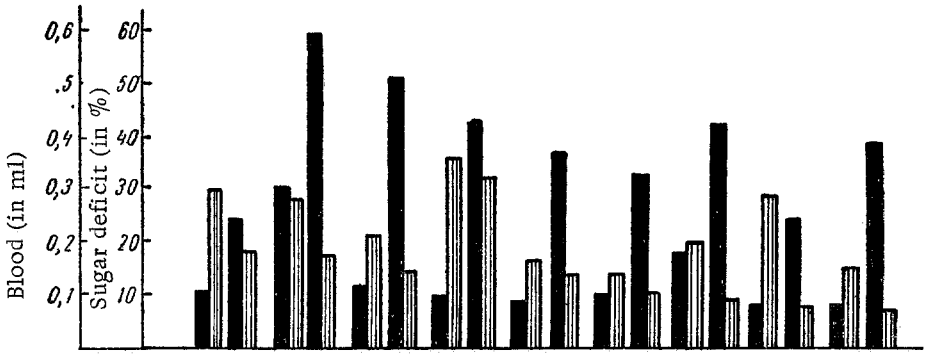

Fig. 2. Relationship between sugar deficit and volume blood flow in regional vessels. For explanation, see text.

portance of such an investigation, if it is remembered that the overwhelming majority of substances are absorbed from the intestine into the blood stream. These problems formed the object of the present investigation.

EXPERIMENTAL METHOD

Acute experiments were carried out on dogs to investigate the absorption of a 10% solution of glucose from two neighboring segments of the small intestine whose regional arterial trunks were perfused with known but different volumes of the arterial blood of that particular animal in unit time. For the perfusion the pump designed by V. M. Khayutin, V. M. Danchakov, and V. L. Tsaturov [2] was used. To prevent the blood from clotting a preliminary injection of heparin was given to the experimental animals. In these experiments it was possible to investigate the relationship between absorption from the small intestine and the volume blood flow in the regional vessels. After introduction of 10 ml of a 10% solution of glucose into the lumen of the intestine, in most cases the whole of the blood draining through the regional vein was collected in a flask. The concentration of sugar in the blood was determined before introduction of the glucose solution and while it remained in the lumen of the intestine, and knowing the precise volume of blood, the amount of sugar absorbed from the intestine into the blood could be calculated. By comparing the results of simultaneous, parallel experiments on two neighboring segments of the intestine, the relationship between absorption and the volume blood flow in the vessels could be determined.

EXPERIMENTAL RESULTS AND DISCUSSION

In experiments in which the regional vessels of a segment of the small intestine were perfused with blood it was observed that the resorption of sugar from the lumen of the intestine and its absorption into the blood stream took place more intensively the greater the volume blood flow in the regional vessels, and vice versa (Fig. 1). Each group of four columns in Fig. 1 corresponds to the results of one experiment. The two columns on the left show absorption (shaded column) when the volume blood flow (black column) was small, and the two on the right show absorption with a larger volume blood flow. It is clear from Fig. 1 that with an increase in the volume blood flow the level of absorption of sugar into the blood stream regularly increased. The volume of blood is expressed in ml/cm length of intestine/min, and the amount of glucose absorbed into the blood in mg.

At the same time, it was noted that not all the sugar absorbed from the lumen of the intestine entered the blood stream. The difference between the amount of sugar absorbed from the intestine and the amount entering the blood was called the sugar deficit. This deficit varied from 5 to 25% as a rule, but sometimes reached 35-40%. The sugar deficit was found, as a rule, to be inversely proportional to the volume blood flow (Fig. 2), i.e., the greater the volume of blood passing through the intestinal vessels, the smaller the sugar deficit. The depiction of the blood flow in Fig. 2 is the same as in Fig. 1. The shaded columns denote the sugar deficit as a percentage of the sugar absorbed from the intestinal lumen at a given rate of flow of blood. It is clear from Fig. 2 that the larger the rate of flow of blood the smaller the sugar deficit. However, the absorption of sugar into the blood stream and the sugar deficit also showed a definite relationship to the level of the animal's general blood pressure. If perfusion of the intestine began against the background of a low general arterial pressure, i.e., if blood of the animal in a terminal state was supplied to the perfused intestine, the level of entry of sugar into the blood stream was very low, and the sugar deficit high. Evidently the absorption of sugar depends in a definite manner on the level of oxygenation of the blood. Cordier and Worbe [5-7] demonstrated a sharp fall in the absorption in the small intestine when a low concentration of oxygen and a high concentration of carbon dioxide are present in the external environment.

	Length of intestine perfused (in cm)	Duration of perfusion (min)	Volume of perfused blood (ml)	Sugar introduced into intestine (mg)	Sugar absorbed into blood (%)	Sugar deficit (in %)
I	16 (jejunum)	20	30	1000	0,5	20
	12 (neighboring distal segment)	20	125	1000	9	12
II	22 (jejunum)	20	75	1100	3	12
	21 (neighboring proximal segment)	20	175	1100	12,25	5
III	23 (jejunum) Perfusion with blood	10	95	1075	16,88	6
	Perfusion with Ringer's solution	10	95	1075	1,68	12

The question of the amount of substances, and especially sugar, absorbed into the blood from the intestinal lumen has become particularly important, for the hypothesis that sugar may enter the blood, not only as glucose, but also as lactic acid or even as intermediate breakdown products of glucose as yet unknown, has recently been widely discussed [13, 14]. Only by determining the quantitative proportion of the substances absorbed into the blood can the form of absorption of any particular substance be established.

Atkinson and co-workers [3] found that of the sugar absorbed from the intestine 70-80% entered the blood as glucose and 7-17% as lactic acid. If the blood supply was insufficient, the lactic acid content rose to 30-40% and the glucose content fell correspondingly.

In experiments with artificial respiration, when a more or less uniform oxygenation of the blood was achieved, the sugar deficit was found to be lowered. Direct experiments were carried out, using oxyhemometry, to determine the relationship between absorption and the level of oxygenation of the blood. Already, however, the many results of investigations in vitro and the results of experiments in which animals were kept in conditions of anoxia [5-7], together with the author's preliminary observations, suggest that a definite relationship exists between absorption and the level of oxygenation of the blood. It is possible that in experiments in vitro a large proportion of the sugar underwent glycolysis, for most authors who have used these methods observed that 40% or more of the sugar was absorbed as lactic acid. In experiments in which a small volume of blood was supplied to the intestine, an increase in the sugar deficit was observed. This also was evidently the result of glycolysis of sugar in the conditions of a reduced blood supply to the intestine, when the absorption apparatus of the intestine, the epithelium of its mucous membrane, and the villi do not receive their normal food supply for maintaining their active function.

Reverting to the findings indicating a direct relationship between absorption and the volume blood flow, it will be noted that in this case the role of the blood is not simply that of a washing fluid: the relationship observed between absorption and the volume blood flow was not a simple linear one (see Fig. 1). Often when the blood flow was doubled, absorption was increased 4 to 6 times. Moreover, during perfusion of the regional vessels of a segment of intestine with equal volumes of blood and Ringer's solution, a marked decrease in the absorption of sugar from the lumen of the intestine into the perfused Ringer's solution was observed by comparison with the amount entering the blood (see table).

On the whole, the results described above demonstrate the physiological role of the blood in the processes of absorption. In particular, the level of oxygenation of the blood would appear to be of great importance. Further investigations of this problem are being carried out.

SUMMARY

Data are presented on the relationship between glucose absorption from the small intestine and the regional blood circulation. Experiments were staged with perfusion of regional arterial trunks in portions of the small intes-

tine with a preset quantity of the blood from a given animal. Perfusion was effected by means of a special perfusion pump. The findings obtained point to a direct relationship between glucose absorption and the blood volume in the regional vessels. It was found at the same time that not all of the glucose absorbed from the intestine lumen was determinable in the blood. The difference between the amount of glucose absorbed from the intestine lumen and the amount taken in by the blood was called the sugar deficit. This deficit was, as a rule, inversely proportional to the blood volume in the regional vessels. The problem of possible relationship between absorption from the small intestine and the level of blood oxygenation is also discussed.

LITERATURE CITED

1. E. S. London and N. P. Kochneva, Arkh. Biol. Nauk., 37 (1935).
2. V. M. Khayutin, V. M. Danchakov, and V. L. Tsaturov, Byull. Éksper. Biol., No. 2, 117 (1958).
3. R. M. Atkinson, B. J. Parsons, and D. H. Smyth, J. Physiol., Vol. 135 (1957), p. 581.
4. Borchardt, Arch. Ges. Physiol., Bd. 219, S. 213 (1928).
5. D. Cordier and J. F. Worbe, Compt. Rend. Soc. Biol., Vol. 149 (1955), p. 110.
6. D. Cordier and J. F. Worbe, Compt. Rend. Soc. Biol., Vol. 150 (1956), p. 1204.
7. D. Cordier and J. F. Worbe, Compt. Rend. Soc. Biol., Vol. 150 (1956), p. 1960.
8. Gellhorn and Northrup, Amer. J. Physiol., Vol. 103 (1933), p. 382.
9. Idem, Ibid., Vol. 106, p. 283.
10. Cellhorn and Scupa, Ibid., Vol. 106 (1933), p. 318.
11. H. J. Hamburger, Arch. Anat. Physiol., Bd. 36, S. 428 (1896).
12. R. Heidenhain, Arch. Ges. Physiol., Bd. 56, S. 579 (1894).
13. S. Hestrin-Lerner and B. Shapiro, Biochim. Biophys. Acta, Vol. 12 (1953), p. 533.
14. Idem, Ibid., Vol. 13 (1954), p. 54.
15. H. Newey, D. H. Smyth, and B. C. Whaler, J. Physiol., Vol. 129 (1955), p. 1.
16. F. Verzar and McDougall, Absorption from the Intestine, London (1936).
17. W. Wilbrandt and Laszt, Bioch. Zbl., Bd. 259, S. 398 (1933).

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
