Influence of ionic environment on intestinal oxygen consumption[1]

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Summary. The oxygen consumption of rat small intestine in vitro is influenced by the anions, chloride and bicarbonate, as well as by sodium.

Previous studies have shown that the oxygen consumption of small intestine in vitro is dependent in part on the presence of sodium in the incubation saline[2-6], and it has been suggested that these observations may reflect the coupling between sodium transport and the utilization of metabolic energy. Studies of ionic movements across the intestinal wall have shown that the transport of sodium is interrelated with the movements of chloride and bicarbonate, and that the jejunal and ileal regions exhibit different characteristics with respect to electrolyte transport[7], but the metabolic correlates of these factors have not been described. In the present study we have investigated the effects of sodium, chloride and bicarbonate on the oxygen consumption of rat jejunum and ileum in vitro.

Methods. The procedure used in our experiments was essentially similar to that described by Martin and Diamond[8] in studies of gall-bladder. Everted segments, 5 cm in length, were cut from the mid-region (jejunum) and distal end (ileum) of the small intestine of male Wistar-strain rats. The segments were allowed to equilibrate for 15 min in a saline bath at 37 °C, and then transferred to a sealed chamber filled with an identical saline and stirred magnetically. The oxygen concentration of the saline in the chamber was monitored over a 5 min period with a Clark-type electrode and amplifier. The incubation saline used in the control experiments was of the following composition in mEq/l: Na^+, 145; K^+, 4.6; Ca^{2+}, 2.0; Mg^{2+}, 2.0; Cl^-, 122; phosphate, 4.6; SO_4^{2-}, 2.0; HCO_3^-, 25. In some experiments the composition of the saline was modified by substitution of choline for sodium, or of methosulfate for chloride and bicarbonate. Salines containing bicarbonate were equilibrated with 95% 0_2/5% 0_2, and bicarbonate-free salines were equilibrated with 100% 0_2. In all cases the pH of the saline was 7.30 ($\pm$ 0.05) and the osmolaity was 305 ($\pm$ 5) mOsm.

Results and discussion. Preliminary experiments showed that the rates of oxygen consumption observed in these conditions were comparable in magnitude with previously published data for this tissue in similar conditions of incubation[2-6,9] and the effects of ionic substitution were fully reversible. The table shows the results of experiments on ionic substitution. In both jejunum and ileum the rate of oxygen consumption was depressed when bicarbonate was omitted from the saline, but the 2 regions of the intestine exhibited differences with respect to the influences of sodium and chloride. In the case of the jejunum omission of chloride did not influence oxygen consumption in any conditions, and omission of sodium did not influence jejunal oxygen consumption when bicarbonate was present in the saline. However, the oxygen consumption of jejunum observed in the absence of both sodium and bicarbonate was significantly smaller than that seen when only bicarbonate was omitted from the saline, indicating that a sodium-dependent component of jejunal oxygen consumption was observed only in the absence of bicarbonate. In contrast, in the studies of ileum, omission of chloride from the saline was associated with a depression of oxygen consumption, and a sodium-dependent component of oxygen consumption was observed in the presence of bicarbonate. The effects of sodium and bicarbonate on ileal oxygen consumption were additive, but the effects of sodium and chloride on ileal oxygen consumption were not additive, and the oxygen consumption observed in the absence of both sodium and chloride was not significantly different than that seen when either sodium, or chloride were omitted separately.

The significance of these observations on ionic determinants of oxygen consumption to the transport physiology of the intestine cannot be identified at present, but a number of interesting parallels between metabolic actions of ions and electrolyte transport processes may be noted. For example, the findings that ileal oxygen consumption is sensitive to both sodium and chloride and that the effects of these ions are not additive, suggests that sodium and chloride may act at a common rate-limiting step in oxidative metabolism, and this may be related to the demonstration that movements of sodium and chloride across ileal epithelium are coupled on a one for one basis by a metabolism-dependant mechanism[10]. Similarly, the finding that jejunal oxygen consumption is independent of the presence of chloride is consistent with the suggestion that jejunal chloride transport is a passive process attributable to diffusion and solvent drag[7]. In addition, our experiments have shown that bicarbonate is an important determinant of oxidative metabolism in the intestine. This anion has been shown to exert a marked stimulatory action on intestinal sodium transport[7], and the present studies indicate that the interaction between bicarbonate and sodium transport may include a metabolic component. In summary, these studies have shown that the oxidative metabolism of intestine is influenced by chloride and bicarbonate, as well as by sodium, and suggest that elucidation of the coupling between electrolyte transport and the utilization of metabolic energy requires consideration of the metabolic actions of anions in addition to those of sodium.

Oxygen consumption of rat small intestine incubated in vitro

Ions omitted from incubation saline	Oxygen consumption Jejunum	Ileum
None	44 $\pm$ 3	45 $\pm$ 2
Na^+	44 $\pm$ 2	36 $\pm$ 2*
Cl^-	39 $\pm$ 2	34 $\pm$ 2*
HCO_3^-	39 $\pm$ 2*	29 $\pm$ 2*
Na^+, Cl^-	44 $\pm$ 4	37 $\pm$ 3*
Na^+, HCO_3^-	21 $\pm$ 1*	19 $\pm$ 1*
Na^+, Cl^-, HCO_3^-	22 $\pm$ 2	21 $\pm$ 2*

Units of oxygen consumption are µmoles h^{-1}/g wet weight of tissue. Results are means $\pm$ SEM for 8 determinations. * Denotes difference from unmodified saline significant at $p < 0.001$.

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