

Effects of Hemorrhage and Tilting on Na, Cl, and H₂O Absorption from the Intestine¹ (35516)

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In a previous publication (1) it was demonstrated that entry of Na, Cl, and H₂O into initially Na-free solutions in the ileum was reduced by hemorrhage. Reduced entry of Na, Cl, and H₂O into the gut lumen indicates that absorption from NaCl solutions might be increased by hemorrhage. In the preceding paper, several morphological and functional similarities between gut and kidney were pointed out and it was suggested that the regulation of salt and water absorption by gut and kidney might also be similar. This paper presents evidence that the gut can indeed alter its ability to absorb Na and Cl against concentration differences following a disturbance of body fluid volume.

Methods. Dogs were dewormed at least 3 days prior to the experiment. Food was withheld for 24 hr before the experiment. Nembutal (30 mg/kg) was employed as anesthetic. A 20-in. segment of terminal ileum (nerve and blood supply intact) was isolated and flushed with saline. All solutions infused or placed in the gut were at a temperature of 39°. The ends of the ileal segment were closed with rubber plugs. A perforated cannula, attached to an external valve, protruded through one of the plugs into the gut lumen. The gut was filled and samples were obtained through the externalized valve, while the gut segment remained in the abdominal cavity.

At the beginning of each period the gut was flushed with 50 ml of a mixture (v/v) of isotonic NaCl (9 g/liter and isosmotic (2) MgSO₄·7H₂O (62 g/liter). The flush solution was immediately withdrawn by gently stripping the gut and aspirating the luminal

contents into a syringe. Recovery of the flush solution was at least 95% complete. MgSO₄ is a poorly absorbed salt which causes H₂O retention but allows NaCl to be absorbed against a relatively high concentration difference (3). Under the conditions of these experiments no more than 5% of the MgSO₄ should be absorbed and the amount absorbed should not be affected by hemorrhage (4). After flushing, the gut was again filled with 50 ml of the NaCl-MgSO₄ solution and 4-ml samples were taken at timed intervals. At the end of the period the gut was emptied and the volume was determined. Measurements of gut absorption were made in the same manner for three periods.

The first period represented a control period. At the end of the control period some of the animals were hemorrhaged either 6, 12, or 25% of their estimated blood volume (8% of body wt). An equilibrium period of 20 min was allowed to elapse before the beginning of the second period. At the end of the second period, the heparinized (10 U/ml) blood was reinfused; and, after 20 min, third-period tests were done. Another group of animals were tilted, head upward, at a 45° angle and second-period tests were done. The animals were returned to the supine position; and third-period tests were done.

Na concentration was determined by flame photometry (Process and Instruments); and chloride concentration, titrimetrically (5). The volume of solution absorbed was determined from the difference between the original volume placed in the gut and the total volume removed. The amounts of ions absorbed were determined in the same manner.

Significance levels of the differences between final ion concentrations and volume of solution absorbed were determined by paired

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t test in which each animal served as its own control and comparisons were made between the control and the two subsequent periods.

Results. The data from hemorrhaged animals are presented in Table I. Hemorrhage at the 6% level had little effect on gut absorption. Hemorrhage at the 12% level caused a significant decrease in the final Na concentration at 40 min and the decrease can also be seen in 20 min. The final Na concentration remains reduced after reinfusion. This suggests a prolonged effect of hemorrhage. Hemorrhage at the 25% level caused a significant decrease in both the final Na and Cl concentration and a significant increase in the volume of H₂O absorbed. The decreased Na concentration is also apparent at 15 and 30 min. The slightly reduced Na concentration at 0 min in period II is not significantly different from that in period I. Following reinfusion, the final Na and Cl concentration reach levels above control values and the Cl concentration is significantly increased. This suggests some damage to the gut which was not apparent at the 12% level of hemorrhage. There were no significant changes in the amount of Na or Cl absorbed in any of the groups. The amount of Na absorbed following hemorrhage is absorbed in a more dilute solution (as determined from the reciprocal of the slope) as compared to either the control or recovery periods (Fig. 1). The slopes (\pm SE) were 6.1 (\pm 1.3), 9.6 (\pm 1.0) and 6.1 (\pm 1.6) for periods I, II, and III, respectively and the slope of period II was significantly different ($p < 5\%$) from the slopes of periods I and III.

The data from animals tilted head upward are presented in Table II. The Na concentration in the lumen is reduced, relative to control levels, following head upward tilting. The reduction is apparent within 15 min and is maintained until the end of the 45-min period. The volume of H₂O absorbed from the lumen is significantly increased following head upward tilting. The Cl concentration in the lumen is only slightly decreased following head upward tilting. There are no significant differences between the control period and the period following return to the supine position. The slopes (\pm SE) of the regression

TABLE I. Ion Concentrations and Volume of H₂O Absorbed (\pm SE) from Ileum Following Hemorrhage.

Time (min)	[Na] (meq/liter)	Vol absorbed (ml)	[Cl] (meq/liter)
6% Hemorrhage (2 animals)			
Control period			
0	72.4 (0.7)		72.6 (2.2)
20	64.0 (6.0)	11.0	50.4 (7.3)
40	57.7 (6.9)	(6.0)	32.8 (10.0)
Posthemorrhage			
0	70.6 (0.4)		72.3 (0.2)
20	62.7 (7.5)	11.0	44.1 (7.7)
40	56.0 (6.0)	(1.0)	32.2 (4.8)
Postreinfusion			
0	71.6 (1.8)		72.4 (1.4)
20	67.0 (6.4)	5.0	52.9 (4.4)
40	59.2 (4.2)	(5.0)	37.3 (6.7)
12% Hemorrhage (5 animals)			
Control period			
0	71.7 (1.2)		73.3 (0.9)
20	65.4 (3.4)	13.8	53.1 (6.0)
40	52.1 (5.2)	(2.0)	36.6 (8.0)
Posthemorrhage			
0	72.0 (1.5)		71.5 (0.4)
20	56.8 (3.3)	12.0	48.4 (6.2)
40	44.9 (4.5) ^a	(4.2)	34.8 (7.1)
Postreinfusion			
0	72.4 (0.7)		73.0 (0.6)
20	57.9 (4.8)	13.8	51.1 (6.7)
40	43.6 (4.5) ^a	(1.2)	38.6 (7.5)
25% Hemorrhage (16 animals)			
Control period			
0	70.6 (2.0)		75.3 (1.5)
15	58.3 (2.4)		56.3 (2.1)
30	43.5 (3.1)	15.1	36.7 (2.8)
45	33.3 (3.4)	(1.5)	26.8 (2.4)
Posthemorrhage			
0	68.2 (1.9)		74.8 (1.4)
15	53.2 (3.0)		55.1 (1.8)
30	38.8 (3.2)	17.7 ^a	33.4 (2.5)
45	27.3 (3.3) ^b	(1.3)	22.6 (2.1) ^a
Postreinfusion			
0	69.6 (1.7)		75.4 (1.4)
15	60.3 (3.1)		60.3 (1.8)
30	47.8 (3.8)	11.1	43.9 (3.0)
45	38.5 (4.2)	(1.8)	34.3 (3.2) ^c

^a As determined by paired *t* test in which each animal served as its own control, differences between control and subsequent periods were significant at (% level): ^b 5; ^c 0.1.

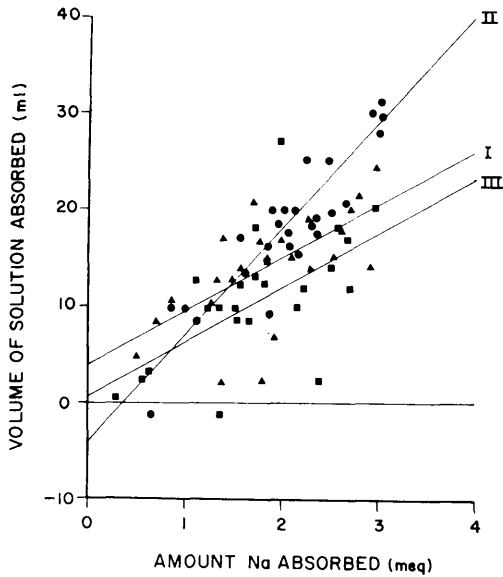


FIG. 1. Amount of Na and concomitant volume of H₂O absorbed from ileum during entire period: (\blacktriangle) control period (I); (\bullet) posthemorrhage (II); and (\blacksquare) post reinfusion (III). Lines represent least squares regression line of all animals represented in Table I.

line of volume absorbed vs Na absorbed were $6.5 (\pm 2.6)$, $5.3 (\pm 1.7)$, and $6.6 (\pm 1.9)$ for periods I, II, and III, respectively, and were not significantly different from each other. There were no significant changes in the amount of Na or Cl absorbed.

In another series of experiments, where blood was obtained from the mesenteric vein draining the gut segment, neither 20% hemorrhage nor head upward tilting significantly altered the Na concentration in the blood. Plasma [Na] in all three hemorrhage periods (9 animals) averaged 136 meq/liter; and in the three periods of animals tilted head upward (5 animals), plasma [Na] averaged 139, 140, and 142 meq/liter in periods I, II, and III, respectively. It was also found that the average final luminal [Na] increased 4.1 and 4.5 meq/liter in periods II and III, respectively (10 animals), compared to period I, even if no experimental change was carried out (unpublished observations). Therefore, the effects of hemorrhage and head upward tilting are opposite to those expected because of deterioration of the gut

due to time and handling. Also, the reduced [Na] in the lumen occurs against either the same or an increased plasma [Na] gradient.

Discussion. The reduced Na concentration in the gut lumen which occurs following 12 and 25% hemorrhage and head upward tilting could reflect either decreased water absorption or an increased ability of the gut to absorb Na against a concentration difference. Since the volume of H₂O absorbed either increases or remains constant, an increased ability to absorb Na against a concentration difference is more likely.

Hemorrhage at the 6% level is not sufficient to stimulate Na absorption. The absorption of Na is more sensitive to hemorrhage than is the absorption of Cl or H₂O since the former is stimulated by 12 and 25% hemorrhage while the latter two are only stimulated by 25% hemorrhage. It seems likely that the initial stimulation of Na absorption causes Cl to follow in order to maintain electrical neutrality and H₂O follows in order to maintain osmotic equilibrium and these latter effects become more pronounced with greater

TABLE II. Ion Concentrations and Volume of H₂O Absorbed (\pm SE) from Ileum Following Head Upward Tilting (14 animals).

Time (min)	[Na] (meq/liter)	Vol absorbed (ml)	[Cl] (meq/liter)
Control period			
0	73.2 (2.0)	18.9	78.7 (1.2)
15	59.3 (2.1)	(1.3)	49.3 (3.5)
30	40.7 (3.4)		29.5 (3.9)
45	30.8 (2.8)		17.4 (3.0)
Head upward tilt			
0	70.7 (1.6)	20.6 ^a	76.1 (1.8)
15	51.7 (2.9)	(1.5)	47.0 (3.8)
30	32.8 (4.0)		26.0 (3.5)
45	20.1 (2.4) ^b		13.7 (3.2)
Supine			
0	72.2 (1.7)	16.6	77.0 (1.4)
15	54.8 (2.7)	(1.6)	51.3 (3.5)
30	38.6 (3.8)		31.0 (3.8)
45	29.8 (3.8)		21.4 (3.3)

^a As determined by paired test in which each animal served as its own control, differences between control and subsequent periods were significant at (% level): 5; and ^b 0.1.

degrees of hemorrhage. Since relatively more H₂O follows Na after hemorrhage, the permeability of the gut to H₂O may be increased by hemorrhage. The absorption of Na and H₂O, but not Cl, are increased by head upward tilting and again it is likely that H₂O follows increased Na absorption.

Although Na and Cl absorption occurred against a greater concentration difference, without measurements of transmural potential, it could not be determined whether this was due to increased active transport. Since the gut lumen becomes more positive as the Na concentration decreases (6) the electrochemical driving force exerted on Na may have remained constant following hemorrhage.

Hemorrhage and head upward tilting are similar in that they both decrease the volume and pressure of blood in the region of the thoracic volume and baroreceptors and initiate cardiovascular reflexes which tend to restore blood pressure (7). Increased Na and H₂O absorption from the gut would also tend to restore blood pressure and is functionally similar to the reduced excretion of salt and H₂O from the kidney following hemorrhage or head upward tilting. Hemorrhage and head upward tilting may increase absorption of Na against a gradient and H₂O through hormonal and/or cardiovascular

changes produced by these procedures (7).

Summary. Hemorrhage of 6% of estimated blood volume does not alter the ability of the gut to absorb Na or Cl against a concentration difference. Hemorrhage at the 12% level increased the ability of the gut to absorb Na against a concentration gradient. Hemorrhage at the 25% level and head upward tilting increased the ability of the gut to absorb Na against a concentration difference and also increased the volume of H₂O absorbed. Causes of the effects were not determined; but it is possible that the effects are related to cardiovascular and/or hormonal responses produced by hemorrhage and head upward tilting.

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