deficiency.[4] Four cases showed an elevated B.B.S. in the blood or cerebrospinal fluid or both, and the other 4 had normal figures. These variations obtained in both acute and chronic cases. Hence the B.B.S. in blood and cerebrospinal fluid cannot be used as an indication of Vitamin B_1 deficiency.

3. A comparatively large group of psychiatric disorders including alcoholic psychoses, schizophrenia, manic-depressive psychoses, miscellaneous psychoses, and behavior and conduct disorders in children were studied. No constant deviation from the normal was found.

4. Paraldehyde causes an elevation of B.B.S. in the blood and cerebrospinal fluid for 24 hours. The drug itself does not bind bisulfite, but our experiments show that the method employed (precipitation with trichloracetic acid) causes a partial hydrolysis of paraldehyde to acetyldehyde, which latter binds bisulfite. Furthermore, patients given paraldehyde, drams 2, by mouth or rectum showed a marked rise in blood and spinal fluid B.B.S. for at least 24 hours. The effect of sodium amytal is under investigation.

5. Our unpublished observations indicate that the B.B.S. is not an accurate measure of the pyruvic acid levels in the blood or cerebrospinal fluid. Several cases of peripheral neuropathy in inebriates were observed with elevated pyruvic acid levels in the body fluids, and a normal total B.B.S.

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Potassium as a Toxic Factor in Intestinal Obstruction.

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A satisfactory explanation of the cause of death in intestinal obstruction is not apparent at the present time. Many hypotheses have been advanced[1-4] and of these the view that potassium is a toxic

[4] Jolliffe, N., and Colbert, C. N., *J. A. M. A.*, 1936, **107**, 642.

[1] Gamble, J. L., and Ross, S. G., *J. Clin. Invest.*, 1925, **1**, 403.

[2] Hartwell, J. A., and Houget, J. P., *J. Am. Med. Assn.*, 1912, **59**, 82.

[3] Knight, G. C., and Slome, D., *Brit. J. Surg.*, 1936, **23**, 820.

[4] Gatch, W. D., and Culbertson, C. G., *Ann. Surg.*, 1935, **102**, 619; Whipple, G. H., Stone, H. B., and Bernheim, B. M., *J. Exp. Med.*, 1913, **17**, 307; Dragstedt, L. R., Dragstedt, C. A., McClintock, J. T., and Chase, C. S., *J. Exp. Med.*, 1919, **30**, 109.

factor, has received attention of late. Scudder, Zwemer and Whipple[5] attributed the earlier development of toxemia in cases of intestinal strangulation and gangrene "to a more rapid and sustained rise in blood potassium, occasioned by loss of fluids."

The present report presents data from experiments in which the blood potassium level was measured, before and at intervals throughout the period of survival, of dogs suffering from intestinal obstruction produced by surgical means.

Methods and Technic. All surgical procedures were performed under ether anesthesia by careful aseptic methods and were accomplished quickly and with a minimum of trauma. Obstructions were produced by (1) Dividing the intestine at the ligament of Treitz and suturing the inverted ends. Dogs 1, 2, 4, 5. (2) Tying off the blood supply to a segment of intestine, thereby producing extensive vascular derangement without segmental obstruction. Dogs 11, 12, 13, 14. (3) Tying off a segment of intestine with heavy cord, *i. e.*, producing segmental obstruction plus vascular derangement (mesenteric thrombosis). Dogs 6, 7, 8, 9, 10.

Blood samples were drawn from the jugular vein or femoral artery of the living animals and the samples taken at death were obtained from the right heart. Oxalate was used as the anticoagulant. Plasma was separated by centrifugation and the proteins precipitated with tungstic acid.

Blood potassium was determined by a slight modification of the method of Truskowski and Zwemer.[6, 7] Duplicate determinations, checked by the analysis and recovery of known quantities of potassium, were conducted in all experiments. Blood chlorides and carbon-dioxide-combining capacity were conducted according to the methods of Whitehorn[8] and Van Slyke and Cullen[9] respectively.

Results. The normal blood potassium level of each dog was followed for a period of 6-39 days since it appeared desirable that emphasis should be placed on the change in the blood potassium level rather than on an absolute value. The normal values observed for whole blood and plasma potassium on 15 dogs appear in Table I (upper portion). The range for normal whole blood potassium values varied from 17.6 to 37.2 mg %, with an average of 23.5. The highest value was observed in the pregnant female dog 6. The nor-

5 Scudder, J., Zwemer, R. L., and Whipple, A. O., *Ann. Surg.*, 1938, **107**, 161.

6 Truskowski, R., and Zwemer, R. L., *Biochem. J.*, 1936, **30**, 1353.

7 Truskowski, R., and Zwemer, R. L., *Biochem. J.*, 1937, **31**, 229.

8 Whitehorn, J. C., *J. Biol. Chem.*, 1921, **45**, 449.

9 Van Slyke, D. D., and Cullen, G. E., *J. Biol. Chem.*, 1917, **30**, 289.

mal range for plasma potassium values varied from 11.8 to 30.6 mg %, average 20.2.

Following operation, we found the blood potassium values in individual experiments were subject to a greater variation than during the control period, but maximum concentrations observed (Table I, lower portion) did not differ markedly from maximum control values. We found no evidence in these experiments of the "rapid and sustained" rise in blood potassium observed by Scudder, *et al.*, in their series. Indeed, we believe that in many of the cases cited by them, the serum potassium was within normal limits during obstruction. In our experiments on dogs 1, 2, 4, 5, 10, 11, 12, and 13, however, the blood picture was not complicated by the loss of fluid by vomiting or exudation into the intestine or peritoneal cavity.

Autopsies conducted at the time of death revealed the absence of septicaemia, peritonitis or gross pathological conditions other than the following: Perforation of the gangrenous intestine occurred in dog 6. A considerable quantity of a characteristic dark, bloody, foul-smelling exudate was found in the intestine of dogs 6, 8, and 9. Analysis of this fluid indicated the presence of 225, 113, 368 mg % of potassium respectively. A peritoneal exudate found in dog 14 contained 121 mg % of potassium. That transperitoneal absorption of this potassium occurred and was responsible for the death of these animals seems unlikely, however, since only dog 8 showed an increase in blood potassium which might be considered toxic. Fifty mg of KCl per pound of body weight was administered to dog 15 (Table I)

TABLE I.
Blood Potassium Values in Experimental Intestinal Obstruction.
Control Period.

Dog No.	Control period, days	Whole blood K mg%			Plasma potassium mg%		
		Samples	Observed variations	Avg	Samples taken	Observed variations	Avg
1.	18	7	21.0-24.2	23.2	6	19.2-23.6	20.5
2.	19	4	19.5-23.5	21.5	5	20.2-21.6	21.3
3.	6	3	19.2-21.5	20.1	3	18.5-21.3	19.6
4.	32	5	19.1-23.0	21.4	6	13.0-24.9	19.6
5.	14	4	21.2-37.2	31.0	5	17.0-26.0	20.4
6.	34	8	17.7-27.4	21.9	8	12.6-23.1	19.1
7.	17	4	18.3-25.6	20.6	4	15.2-19.6	17.4
8.	22	6	17.8-32.4	22.9	7	14.0-30.2	21.8
9.	19	6	19.6-32.3	23.5	6	16.6-23.2	19.7
10.	18	6	22.6-31.3	26.7	6	16.3-25.4	20.9
11.	39	8	20.4-32.0	23.2	8	14.4-30.6	20.3
12.	28	13	17.6-27.5	22.4	13	11.8-24.6	18.4
13.	34	11	18.0-28.2	22.4	9	13.1-26.1	19.2
14.	35	10	20.7-35.0	26.2	3	19.8-26.8	22.3
15.	26	7	19.9-30.0	26.5	7	19.6-29.5	23.1
Total or avg		147	17.6-37.2	23.5	96	11.8-30.6	20.2

TABLE I. (Continued)
Period of Experimental Obstruction.

Dog No.	Type of exp. Obstruction	Survival period	Samples taken	Whole blood K: Observed variations	Whole blood K: At near death	Plasma potassium: Observed variations	Plasma potassium: At near death
1.	Intestine severed below ligament of Treitz. Ends sutured	14½ days	20	16.9-30.2	28.1	9.2-37.6	21.1
2.	*Ibid.*	4½ ''	7	17.8-30.2	23.9	15.5-20.9	15.5
3.	*Ibid.*			Gangrene evident			
4.	*Ibid.*	15½ ''	13	16.1-27.1		12.4-23.2	
5.	*Ibid.* Pregnant female	2½ ''	6	22.3-28.9	35.5	25.6-26.9	49.0
6.	Strangulated intestinal loop 18 in. just below ligament of Treitz	24 hr	3	22.4-23.9	22.4	21.4-23.2	21.4
7.	*Ibid.* 9-in. loop	24 ''	4 hr	17.7-24.6	23.6	13.5-16.2	13.6
8.	*Ibid.*	24 ''	4			22.0-23.2	44.8
9.	*Ibid.*	26 ''	3	27.0-34.1	36.1	21.5-22.5	21.5
10.	*Ibid.* 2-in. loop	36 ''	7	23.7-30.1	35.9	15.4-33.9	15.4
11.	Ligated mesentery blood supply about 12 in. of intestine. Blood vessels ligated	11 ''	5	17.7-28.0	28.0	19.3-19.9	35.3
12.	*Ibid.*	46 ''	9	22.2-30.4	34.6	18.4-32.6	24.1
13.	*Ibid.*	36 ''	11	24.6-31.7	36.0	20.1-34.0	24.9
14.	Blood vessels of mesentery ligated *Ibid.*	48 ''	8	18.2-30.9	25.4	Chlorides varied 527-589 mg%	
15.	Control female pregnant appendectomy. Aborted 3rd day after operation		11	18.5-30.7		11.8-25.7	Survived
	Injection of 1.9255 g KCl (50 mg KCl per lb)		7	20.8-32.6		18.0-26.5	Survived
Total or avg			118	16.1-34.1		9.2-37.6	

subsequent to an appendectomy, which served as a control operation. This dog, a pregnant female deprived of food and drink, showed no toxic symptoms of potassium poisoning; yet the observed changes in the concentration of the blood potassium were not unlike those found in dogs dying from intestinal obstruction.

Dogs 1, 2, 4, 5, 10, 11, 12, and 13 were characterized by the almost total absence of a fluid exudate either in the intestine itself or in the peritoneal cavity, and the dogs did not vomit. Obviously, death cannot be ascribed to loss of fluid in these 8 experiments.

The changes of relatively small magnitude in blood potassium observed in the present study could well be accounted for on the basis

of purely mechanical factors such as (1) change in plasma volume, (2) change in resistance or rate of blood flow, or, since one of the earliest evidences of a disturbance in intestinal obstruction is a lessening of urinary output, (3) to anuria. Baetjir[10] noted the interesting fact that potassium escapes from the muscles and elevates the blood potassium when the blood flow through a limb is reduced by hemorrhage, vasoconstriction or clamping of an artery. Baetjir found a marked increase in plasma potassium to occur under these conditions. Similarly, Dennis and Moore[11] observed that ischemia of the functioning heart of the cat led to a marked rise in the potassium content of the venous blood. It is of interet here also, to note that periods of anoxia of 2-4 minutes' duration result in an average increase of blood potassium of 30% in the dog (Dennis and Mullin[12]), or average increase of 120% for 4-5 minute of asphyxia in the cat (Cattell and Civin[13]). The administration of adrenalin (Marenzi and Gerschman,[14] D'Silva,[15] and others); histamine (Thaler[16]), or central nervous stimulation (Cloella, Fisher and van der Loeff[17]) all result in effecting a marked rise in serum potassium. The mechanisms involved in these changes may well account for changes observed in the blood potassium in intestinal obstruction. The changes in blood potassium observed by the above group did not result in apparent damage since all animals survived, although changes in serum, plasma or whole blood potassium values were greater than those observed in the present study. Thus it becomes increasingly difficult to assume that potassium is a toxic factor in intestinal obstruction.

In view of the specific action of potassium on the heart, the observations of Winkler, Hoff and Smith[18] appear to us further to substantiate the view that potassium cannot be considered as contributing to the cause of death in intestinal obstruction. These workers studied the electrocardiographic changes which resulted following a constant elevation of the serum potassium in the dog,

10 Baetjir, A. M., *Am. J. Physiol.*, 1935, **112**.

11 Dennis, J., and Moore, R. M., *Am. J. Physiol.*, 1938, **123**, 443.

12 Dennis, J., and Mullin, F. J., PROC. SOC. EXP. BIOL. AND MED., 1938, **38**, 560.

13 Cattell, M., and Civin, H., *J. Biol. Chem.*, 1938, **126**, 635.

14 Marenzi, A. D., and Gerschman, R., *Compt. rend. soc. biol.*, 1937, **124**, 382; *Rev. soc. argentia biol.*, 1936, **12**, 424.

15 D'Silva, J., *J. Physiol.*, 1937, **90**, 303.

16 Thaler, J. I., PROC. SOC. EXP. BIOL. AND MED., 1935, **33**, 368.

17 Cloetta, M., Fisher, H., and van der Loeff, M. K., *Arch. exp. Path. Pharm.*, 1934, **174**, 589.

18 Winkler, A. W., Hoff, H. E., and Smith, P. K., *Am. J. Physiol.*, 1938, **124**, 478.

produced by intravenous injection of isotonic KCl. Intraventricular block began when the serum potassium reached a concentration of 10mM per liter (39 mg %) and cardiac arrest took place when the critical concentration of 14.16 mM per liter (55-63.5 mg %) was reached. Ectopic arrythmias were not observed to occur and all dogs survived the experiment despite an average increase in potassium of 300%. Furthermore, according to Scudder, Smith and Drew,[19] the plasma potassium of 4 dogs receiving isotonic potassium in lethal doses reached 50.5 mg % before cardiac arrest and death occurred. Blood potassium values of this order were not observed in the present series. We feel that the quantitative changes in the biochemical composition of the blood as observed in intestinal obstruction are incidental to the disturbances in blood volume, concentration, rate of flow and tissue metabolism rather than the cause of the prostration and death.

Bisgard, McIntyre and Osheroff[20] studied the behavior of serum potassium in the blood of dogs suffering from high intestinal obstruction or duodenal fistulas. They found no evidence that the potassium or a change in the sodium-potassium ratio contributed to the production of symptoms or cause of death. Our results confirm this view. Recently Falconer, Osterberg and Bargen[21] arrived at a similar conclusion as a result of their observations on patients suffering from intestinal obstruction.

Summary. It has been shown that hyperpotassemia cannot be considered as a contributing factor to the cause of collapse and death in experimental intestinal obstruction in the dog.

19 Scudder, J., Smith, M. E., and Drew, C. R., *Am. J. Physiol.*, 1939, **126**, 337.

20 Bisgard, J. D., McIntyre, A. R., and Osheroff, W., *Surgery*, 1938, **4**, 528.

21 Falconer, M. A., Osterberg, A. E., and Bargen, J. A., *Proc. Staff Meetings Mayo Clinic*, 1939, **14**, 22.