STUDIES IN BLOOD PRESERVATION

The Serum Potassium of Cadaver Blood

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An observed increase in plasma potassium of a patient dying from an automobile accident (9) suggested a further investigation of this base in cadaver blood, especially as this source has been used extensively for transfusions (12).

The concentration of potassium within the intact red blood cells is twenty times that of the plasma. In this respect, the erythrocyte resembles the marine alga, valonia macrophysa. In the latter, Osterhout (5) explains the higher internal concentration of potassium as due not to the formation of insoluble compounds, but due chiefly to diffusion constants and concentration gradients, the latter depending on partition coefficients (7, 8).

Osterhout's (6) quantitative studies on cell sap of valonia have revealed a loss of potassium to be associated with injury. Another factor which causes these cells to lose potassium is an increase in ammonia. Jacques and Osterhout have shown that if the concentration of ammonia in sea water were raised by 0.0001 molar, there occurs a rapid exit of potassium from these cells.

Methods. Under sterile precautions the blood was collected from the heart on a number of unselected cases; one portion was cultured, and the remainder was introduced into a Sanfort-Magath hematocrit tube and centrifuged for one hour. The average time of separation of serum from the cells was 35 hours after death. Potassium was determined by the argenticobaltinitrite method (10, 11), the final color being read on an Evelyn photoelectric colorimeter (2).

Results. The average concentration of the serum potassium in these 27 cases was 101 milligrams per cent. These results contrast with our average of 17.2 milligrams per cent in the plasma of normal venous blood and the average of 29.7 milligrams per cent in the plasma of cardiac blood taken at death (9) (Table II).

HIGH SERUM VALUES IN CADAVER BLOOD

This high serum potassium approximately 3.5 times the concentration of that found at death and nearly 6 times greater than normal illustrates the rapid diffusion of potassium in cadaver blood. It takes refrigerated fresh blood 110 hours to reach approximately this same concentration. Factors affecting this rapid diffusion are many. Among them temperature is one, for preserved blood is usually placed in the icebox immediately, whereas many hours may elapse between death and storage of the cadaver. A second factor may be the ammonia concentration.

There has been much difficulty in determining the free ammonia in circulating blood. Folin and Dennis were the first to find values under 0.10 milligram ammonia-N per 100 milliliters. Subsequently a value of 30 gamma (0.03 mg.) per 100 milliliters was considered to represent the free ammonia-N in circulating human blood. Conway with his isothermal distillation method has established the true value to be "less than one-tenth this amount, or less than one part in thirty million."

Our interest in ammonia resulted from our curiosity about the high serum potassium values in cadaver blood. With the cobaltinitrite method it has long been known that if ammonia is present, there is a quantitative precipitation of ammonium cobaltinitrite along with the potassium salt.

$$3\,NH_4 + Co(NO_2)_6 — (NH_4)_3Co(NO_2)_6$$
$$3\,K + Co(NO_2)_6 — K_3Co(NO_2)_6$$

Subsequent analysis for ammonia on several cadaver bloods gave the highest value to be

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TABLE I.—SERUM POTASSIUM OF CADAVER CARDIAC BLOOD OBTAINED AT AUTOPSY

Hospital No. Date of death	Initials, sex, and age	Principal autopsy findings	Serum potassium as milligrams per cent
534998 7-3-38	J.M., M., 27	Rheumatic endocarditis	54.7
531679 3-31-38	T.G., M., 45	Carcinoma of stomach; duodenojejunostomy	59.2
37890 5-10-38	J.G., F., 31	Tuberculous leptomeningitis	60.9
37862 8-18-38	C.V., M., 57	Glioblastoma of cerebral hemisphere	64.5
547187 5-23-38	M.H., F., 50	Hyperplasia of thyroid with hyperthyroidism	70.0
538189 4-12-38	M.L., F., 56	Congenital malformation of heart, cardiac hypertrophy and dilatation	70.4
11647 4-6-38	H.LaC. M., 69	Multiple fractures of skull	72.0
37736 4-25-38	C.O'K., F., 35	Abscesses of cerebellum	73.5
487166 7-22-38	A.R., M., 53	Cardiac hypertrophy and dilatation, clinical diagnosis: hypertension, uremia	76.6
522385 4-18-38	L.H., F., 41	Chronic myeloid leucemia	77.4
289643 4-19-38	M.F., F., 35	Carcinoma of female mammary gland with multiple metastases to lymph nodes	77.7
548449 4-27-38	I.B., F., 27	Placenta prævia, cesarean section	80.8
545832 4-11-38	G.H., M., 66	Carcinoma of stomach, partial gastrectomy	87.2
433652 3-2-38	R.R., M., 62	Subacute glomerulonephritis, pneumonia, clinical diagnosis: hypertension, uremia	97.0
552683 6-21-38	B.T., M., 56	Acute gangrenous appendicitis with peritonitis	98.0
367436 8-14-38	W.R., M., 65	Carcinoma of sigmoid, resection of colon	98.3
451845 4-30-38	H.R., F., 48	Lymphosarcoma of lymph nodes, secondary lymphosarcoma of dura mater, multiple abscesses, laminectomy, resection of tumor	98.9
250743 4-27-38	S.F., F., 64	Arteriolar nephrosclerosis; clinical diagnosis: uremia	110.0
284144 3-18-38	W.H., M., 13	Rheumatic endocarditis	118.0
37623 5-9-38	M.S., F., 52	Meningioma, olfactory groove, operation: bilateral cervical sympathectomy	118.0
520112 3-31-38	G.M., F., 40	Subacute bacterial endocarditis due to gram positive coccus, splenectomy	118.6
543474 4-4-38	J.S., M., 67	Carcinoma of colon, colostomy; resection of carcinoma of colon	128.0
552258 6-22-38	V.E., F., 58	Carcinoma of stomach	141.0
294654 3-7-38	R.R., F., 31	Rheumatic endocarditis	160.0
549302 5-25-38	K.S., M., 68	Acute splenic tumor, clinical cause of death: cerebral thrombosis	166.0
546147 4-8-38	K.B., F., 63	Venous angioma, temporal lobe	175.0
545415 4-17-38	R.M., M., 58	Carcinoma of kidney, pneumonia	180.0

TABLE II.—PLASMA POTASSIUM OF HUMAN BLOOD*

Number of samples analyzed	Source of sample	Plasma potassium expressed as			
		Milligrams per cent		Millimols per liter	
		Average	Range	Average	Range
73	Venous blood from normal young adults	17.2	13.5– 21.5	4.4	3.5– 5.5
13	Cardiac blood removed at death	29.7	24.0– 38.0	7.6	6.1– 9.7
27	Cardiac blood removed at autopsy	101.0	54.7–180.0	25.8	14.0–46.0

*Centrifuged at 2,000 r. p. m. for 1 hour after which the plasma or serum was immediately separated from the cells.

The average time of separating the serum from the cells after death was 31.5 hours.

The figure for each determination represents the mean of 2 aliquot samples.

TABLE III.—THE EFFECT OF ADDING AMMONIA TO BLOOD ON POTASSIUM DIFFUSION TEMPERATURE 38° C.

Date	Time in hours from phlebotomy	Potassium as milligrams per cent in plasma of citrated blood		
		Control	Ammoniated blood	Difference between specimens
3-18-39	0	20.9*	....	....
	2	19.6	30.6	11.0
	4	20.0	29.0	9.0
	6	20.3	31.7	11.4
3-19-39	8	21.9	33.2	11.3
	15	23.0	40.0	17.0
	18	27.2	43.9	16.7
	23	30.9	52.8	21.9
3-20-39	31	40.4	55.7	15.3
	39	79.9	98.1	18.2
3-21-39	71	121.0	120.0	1.0

*Plasma potassium of undiluted blood. Each figure represents the mean of two aliquots. Control: 225 c. cm. of blood and 25 c. cm. of 2.5 per cent sodium citrate.

Ammoniated blood: 250 c. cm. of blood, 25 c. cm. of 2.5 per cent sodium citrate.

1.3 milligrams per 100 milliliters. We concluded, therefore, that the apparent high potassium values were not due to ammonia but were genuine. This concentration of ammonia, however, is far in excess of that which Jacques and Osterhout have shown causes potassium to leave valonia.

To ascertain whether the addition of ammonia causes a similar diffusion of potassium from red cells, sufficient ammonium chloride was added to one of two similar portions of citrated blood to bring its concentration to approximately 0.01 molar. These specimens were stored in identically shaped bottles in a water bath kept at 38 degrees centigrade throughout the experiment (Table III).

The results indicate that with the addition of ammonium chloride, a prompt rise in the plasma potassium takes place and the rate of diffusion of potassium is more rapid in the ammonia flask than in the control during the first seventy-one hours of the experiment.

SUMMARY

The increase in serum potassium is more rapid in cadaver than in fresh blood stored in a refrigerator at 4 degrees centigrade.

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