THE ABILITY OF THE BODY TO RETAIN AN INDIFFERENT GAS IN A STATE OF SUPERSATURATION

COMMUNICATION I. THE RELATIONSHIP BETWEEN THE PERMISSIBLE SUPERSATURATION AND CERTAIN BIOPHYSICAL AND BIOCHEMICAL INDICES IN THE BLOOD AND THE HYDROPHILIA OF THE SKIN

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With a fall in the environmental pressure of man, sorption of indifferent gases into the body tissues is reduced. When the rate of fall of pressure does not exceed a certain value, the body frees itself from excess of gas by a process of molecular diffusion. If this condition is not satisfied the indifferent gas is released directly into the tissues in a phase of bubble formation. The development of these gas bubbles when the environmental pressure falls is the fundamental cause of decompression sickness. Persistent bubbles begin to form only when there is a definite discrepancy between the tension of the gas in the body and the general pressure. The value of this pressure difference is given the name of the permissible supersaturation (PS).

From work by several authors [5, 13] it may be assumed that the PS varies from one individual to another. The object of the present investigation was to try to explain the mechanism of these individual differences in the ability of the body to retain an indifferent gas in a state of supersaturation.

We could find no reports in the literature which were directly concerned with the solution of this problem. In carrying out our investigation we had, therefore, to start from a predetermined hypothesis based mainly on results described by M. P. Brestkin [4], American workers [12], D. N. Nasonov and V. Ya. Aleksandrov [7], N. V. Lazarev [6] and M. I. Yakobson [11].

In the present work we investigated the relationship between the individual ability of the body to withstand a definite pressure difference without developing decompression sickness and the following blood indices: the serum protein content, the hemoglobin, the erythrocyte sedimentation rate, the mean corpuscular volume, and also the hydrophilia of the skin.

EXPERIMENTAL METHOD

Experiments were carried out on 7 male dogs of average nutritional level kept on a strict intake of water and food. Twice a week 4 - 4.5 ml of blood was taken from the anterolateral metatarsal vein of each dog, the body temperature taken and a test of the hydrophilia of the skin performed [8]. After this test the dog was placed for 4 hours in a compression chamber at normal atmospheric pressure; occasionally the animal was weighed and its pulse rate taken before being placed in the chamber.

The mean corpuscular volume of the blood was determined with the hematocrit and the hemoglobin by a colorimetric method [3]. A small portion of the blood taken was mixed with ammonium and potassium oxalate in order to obtain plasma and from the rest of the blood, serum was obtained by a method ensuring no contamination with hemoglobin [2]. The total protein content of the plasma was estimated by the biuret reaction and in the serum — the total protein content and the albumin content after precipitation of the globulins with saturated

TABLE 1

Values of the Permissible Supersaturation of the Body with Nitrogen in the Experimental Dogs

V'yunok		Pestryi		Polkan		Mars		Bobik		Tsyganok		Atlas	
date	PS	date	PS	date	PS	date	PS	date	PS	date	PS	date	PS
30/V 1956 r.	1.72	27/X 1956 r.	1.72	12/VI 1956 r.	1.56	8/V 1956 r.	1.4	24/IX 1956 r.	1.4	19/XI 1956 r.	1.24	10/V 1956 r.	1.08
8/VI	1.72	23/XI	1.72	20/VI	1.56	22/V	1.4	24/X	1.4			24/V	1.08
18/IX	2.04	7/1 1957 r.	1.72	13/IX	1.56	6/IX	1.4	26/XI	1.4			5/IX	1.08
28/IX	2.04			30/XI	1.56	29/X	1.56						
14/1 1957 r.	2.04					8/1 1957 r.							

sodium sulfate solution [15]. In addition two precipitation reactions were carried out with the serum: zinc sulfate [10] and coagulating [1]. For the colorimetric measurements we used the FÉK-M colorimeter.

After the preliminary experiments had given clear results we proceeded to measure the PS by the method of I. I. Savichev and A. N. Bukharin [5]. For this purpose, after taking the blood and carrying out the test of hydrophilia of the skin, we placed the dog in the chamber and raised the pressure to 2.4 absolute atmospheres. At the end of 4 hours the pressure was lowered to atmospheric within 50-60 sec. If signs of decompression sickness appeared, a therapeutic recompression was carried out. In the absence of signs of the sickness, after a minimum of two days the dog was again placed in the chamber, this time at a pressure of 0.2 absolute atmos above the previous. This continued until after release from any pressure decompression sickness developed. The value of the PS was taken to be the maximum pressure which did not cause the sickness. The PS was expressed by the formula $\Delta_p = PN_2 - P_A$, where PN_2 is the nitrogen pressure in the tissues after exposure for 4 hours, in practice equal to the partial pressure of N_2 in this total pressure [14]; P_A is the atmospheric pressure, equal to 1 absolute atmos.

The results of measurement of the blood indices were analysed statistically by the rules generally accepted in experimental work [9].

EXPERIMENTAL RESULTS

As seen from Table 1, over a period of 3-8 months small variations in the PS were observed in only 2 experimental dogs.

In order to fulfil the main task of the investigation, we carried out 194 experiments in 16 series. The experimental results are shown in Table 2. In this table the significant arithmetic mean values of all indices are given, obtained in accordance with the variation of the index from 27 to 3 separate values. In the two lower lines of the table are indicated the statistical criteria of the relationship, in this case also only when of proved significance.

It follows from the results in Table 2 that there is a close statistical relationship between the PS and the protein composition of the serum: the higher the albumin content and the lower the globulin content, the greater the degree of supersaturation which the dog as a rule is able to withstand. This relationship is seen particularly clearly from a comparison of the PS and the albumin-globulin ratio (A/G). This relationship between the PS and A/G is shown graphically in the Fig.*

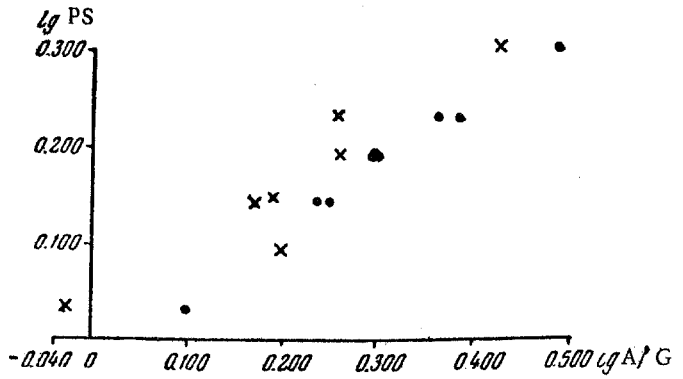
The character of distribution of the points on the graph suggests the presence of an almost proportionate relationship between the PS and the value of the A/G. It is noteworthy that the points which relate to the observations made in the autumn (x) are situated to the left of those relating to the winter and spring(●). Evidently in the autumn some factor acts on the body which causes the PS to increase without

* The graph is drawn to a logarithmic scale in order to reduce its size.

TABLE 2

The Relationship between the PS and Various Biophysical and Biochemical Indices

Name of dog	Age (in years)	Serial number of experiments	PS, atmos.	Body weight, kg	Body temperature, °C	Pulse rate, per minute	mean corpuscular volume, %	plasma proteins, g%	Serum proteins, g%	Albumins, g%	Globulins, g%	Albumin/Globulin ratio	Zinc sulfate reaction, extinction	Coagulation test (highest dilution with coagulation)	Hemoglobin, extinction	ESR, mm/hr	Time of absorption of physiological saline, minutes
V'yunok	1—2	1	1.72	19.4	39.0°	—	40.4	5.62	5.40	3.72	1.62	2.32	—	0.31	0.418	3.0	41
		2	2.04	18.8	38.8°	88	42.3	5.72	5.55	4.05	1.53	2.68	0.035	0.21	0.516	2.1	29
		3	2.04	20.6	38.9°	89	44.5	5.82	5.72	4.30	1.40	3.09	0.020	—	—	—	33
Pestryi	3—4	4	1.72	21.6	38.2°	100	52.6	6.06	6.01	3.85	2.14	1.82	0.026	—	—	—	40
		5	1.72	22.1	38.2°	84	51.2	—	6.28	4.46	1.82	2.44	0.024	—	—	—	46
Polkan	1—2	6	1.56	29.8	38.4°	—	41.5	6.42	6.11	4.11	2.01	2.10	—	0.26	—	—	44
		7	1.56	28.4	38.8°	84	42.7	6.01	5.73	3.64	1.97	1.82	0.046	0.22	—	—	31
		8	1.56	26.4	38.5°	63	45.3	6.43	6.25	4.15	2.10	2.00	0.060	—	—	—	34
Mars	4—6	9	1.40	24.3	38.5°	—	43.8	5.75	5.54	3.54	1.97	1.79	—	0.25	0.450	3.0	64
		10	1.40	24.4	—	91	42.7	5.91	5.66	3.34	2.29	1.49	0.034	—	—	—	34
		11	1.56	25.0	—	75	42.7	6.11	5.99	4.06	1.94	2.10	0.028	—	—	—	43
Tsyganok	2—3	12	1.24	19.2	38.8°	79	43.4	5.93	5.67	3.47	2.20	1.59	0.072	—	—	—	25
Bobik	5—7	13	1.40	21.4	38.3°	105	48.9	6.36	6.03	3.67	2.41	1.55	0.075	—	—	—	40
		14	1.40	20.1	38.2°	92	44.4	6.10	6.05	3.85	2.21	1.73	0.049	—	—	—	45
Atlas	3—4	15	1.08	24.3	38.6°	—	45.6	6.18	5.80	3.20	2.61	1.26	—	0.30	0.446	3.0	64
		16	1.08	24.2	38.5°	80	46.7	6.34	6.04	2.91	3.13	0.93	0.187	0.24	0.508	7.0	54
Criteria of the relationship between the PS and the given indices	Coefficient of correlation, r		—	—	—	—	—	—	—	+0.80	—0.89	+0.94	—	—	—	—	—0.50
	Correlation ratio η		—	0.89	—	0.89	—	—	—	—	—	—	0.95	—	—	—	—



Relationship between the value of the permissible supersaturation of the body with nitrogen and the value of the albumin-globulin ratio of the blood serum.
x) Observations made in the autumn; ●) observations made in the winter and spring.

at the same time affecting the composition of the blood proteins.

The correlation between the PS and the composition of the serum proteins is confirmed both by the presence of a relationship between the PS and the zinc sulfate test, although in this case the relationship is not linear but curvilinear, in the form of a hyperbola.

A curvilinear relationship was also found between the PS on the one hand and the body weight and pulse rate on the other. The curve in this case was S-shaped. It is difficult to understand the meaning of this phenomenon without further investigation.

The relationship between the PS and the hydrophilia of the skin merits attention. The closeness of this relationship is considerably less than between the PS and the protein composition of the serum, but the shape of the graph here is quite definite and is linear in character: The higher the PS the greater the hydrophilia.

Hence the physiological indices most closely connected with the PS are the albumin and globulin content of the blood serum.

It is interesting that in cases when variations in the PS were observed, as for instance in the dogs Mars and V'yunok, the increase in the PS was accompanied by an increase in the mean value of A/G. Consequently here also we find confirmation of the relationships which have been discovered.

On the whole the results given in this paper demonstrate the existence of a well defined relationship between the ability of the body to retain nitrogen in a supersaturated state, the protein composition of the blood and the water metabolism. Evidently differences in the colloidal properties of the blood and other fluid tissues are the factor which to a large extent determines the value of the permissible supersaturation of the body with an indifferent gas.

SUMMARY

The relationship of the ability of the body to retain nitrogen in condition of oversaturation to the qualitative pecularities of the blood proteins and to skin hydrophilism was demonstrated in chronic experiments on dogs.

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