THE ROLE OF INTEROCEPTORS IN THE REGULATION OF OXYGEN SATURATION OF ARTERIAL BLOOD

COMMUNICATION I: THE ROLE OF THE CAROTID SINUS ZONES IN THE REGULATION OF OXYGEN SATURATION OF ARTERIAL BLOOD IN HYPOXIA

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The degree of oxygen saturation of arterial blood is known to be closely related to the partial pressure of oxygen in the surrounding atmosphere. Under conditions of lowered partial pressure of oxygen, compensatory changes in a number of functions (respiration, circulation, composition of blood etc.) occur which are designed to maintain the vital processes of the organism.

The role of interoceptive zones has, however, been inadequately investigated with reference to the dynamics of oxygen saturation of the blood.

W. Grant [2] determined oxygen saturation of the blood in rabbits with denervated carotid sinus and found that inhalation of a mixture containing 10% oxygen led to a drop in the oxygen saturation of arterial blood down to 41% whereas in control animals this value remained within the range of 78-89%. These data were not confirmed by M. Terzioglu, E. Goral and J. Bardav [3].

The aim of the present investigation was to discover more precisely the role of the carotid sinus zones in the dynamics of oxygen saturation of arterial blood under conditions of reduced pressure. The technique of continuous oxyhemometry as developed by Professor E. M. Kreps [1] was employed in this work.

EXPERIMENTAL

The investigation was carried out on cats and rabbits; these were "elevated" in a decompression chamber at the rate of 15 m/sec and exposed for 15-20 minutes to an "altitude" of 7500 m. The rate of "descent" varied within the range 10-15 milliseconds.

The subjects for the experimental series consisted healthy, unoperated animals—4 rabbits and 3 cats, and 5 rabbits and 3 cats which had been subjected to denervation of the carotid sinus zones $2\frac{1}{2}$ months previously. Altogether 47 observations were made.

The animal was attached to a stand with its back up, the head was placed in a holding apparatus. The "saturation measuring device" was attached to the pinna which had been carefully shaved and washed.

The experimenter was placed in the decompression chamber with the animal and took readings every

minute of the relative indications as shown by the apparatus 0-26 (upper scale). The device was set at 100% saturation before the experiment when the animal was inhaling pure oxygen for 2-3 minutes supplied by way of a special mask.

In order to convert the relative readings into percentage saturation a direct Van Slyke calibration was made on 8 analyses on 4 rabbits and 10 analyses on 4 cats. Conversion graphs for the relative readings into percentage saturation are given in Fig. 1, a for cats and 1, b for rabbits.

RESULTS

One series of experiments was carried out on healthy, unoperated animals. The degree of oxygen saturation of arterial blood prior to the "elevations" remained within the limit of 93% for cats and 91% for rabbits. As the atmosphere became more rarefied a more or less regular lowering of oxygen saturation of the blood was noted. On reaching decompression corresponding to 7500 m (287 mm Hg) the saturation dropped to 57-58%. Nonetheless during such exposure in the majority of experiments some rise of saturation was observed; it reached approximately 70% towards the 15th-20th minute.

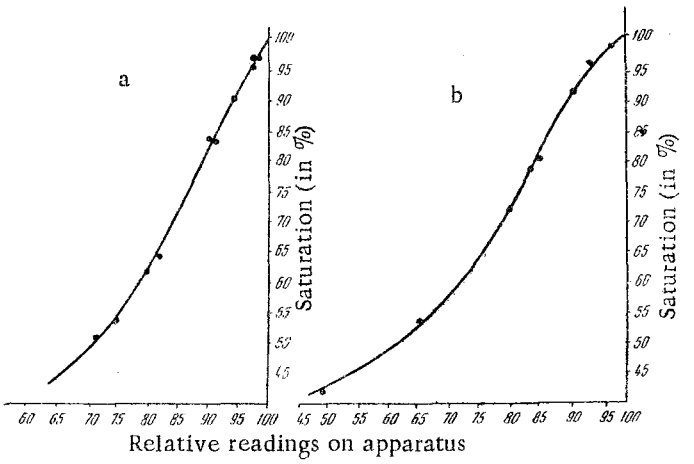

Figure 1. Conversion curve for relative readings into % saturation: a) cats; b) rabbits. Circles indicate results of direct blood gas analyses by the Van Slyke method.

During the increase of pressure to normal the degree of saturation was restored to the original values.

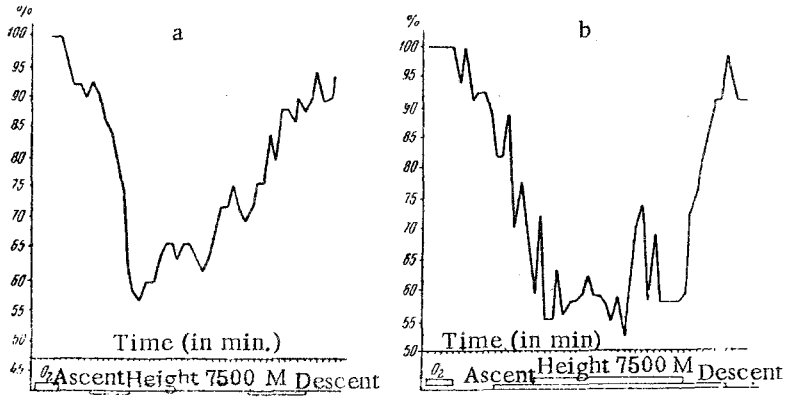

Figure 2. Dynamics of oxygen saturation of arterial blood. a) in intact cat (No. 22) during "elevation" to a "height"; b) in intact rabbit (No. 34). Ordinates – % saturation, abscissae – points from readings taken every minute. Lower line – experimental conditions: initial setting of apparatus at 100% saturation on inhalation of pure oxygen; period of "elevation" to an "altitude"; period of exposure to an "altitude" of 7500 m; period of "descent"; control under normal conditions after the experiment.

TABLE 1

Degree of Oxygen Saturation of Arterial Blood on "Elevation" to 7500 m in Intact Animals (5 minute intervals).

No. of animal	Oxygen saturation of blood prior to elevation		At an elevation of 7500 m												After descent	
			1st minute		5th minute		10th minute		15th minute		20th minute		25th minute			
	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale
Cats																
3	94	96	58	78	60	79	68	83	62	80	64	81	66	82	94	96
22	92	95	60	79	66	82	72	85	72	85	—	—	—	—	94	96
28	94	96	56	76	58	78	81	64	72	85	—	—	—	—	94	96
Average	93.3	—	57	—	61.3	—	73.6	—	69	—	—	—	—	—	94	—
Rabbits																
34	89	92	59	75	56	73	59	75	59	75	69	81	59	75	91	93
36	94	95	55	72	89	95	82	88	72	83	62	77	63	78	94	95
45	91	93	59	75	72	83	80	87	72	83	—	—	—	—	91	93
58	92	94	62	77	55	72	63	78	70	82	—	—	—	—	92	94
Average	91.5	—	58.7	—	68	—	71	—	68	—	65.5	—	61	—	92	—

TABLE 2

Degree of Oxygen Saturation of Arterial Blood on "Elevation" to 7500 m in Animals with Denervated Carotid Sinus Zones (5 minute intervals).

No. of animal	Oxygen saturation of blood prior to elevation		At an elevation of 7500 m												After descent	
			1st minute		5th minute		10th minute		15th minute		20th minute		25th minute			
	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale	%	Readings on apparatus scale
Cats																
16	90	94	55	75	57	77	53	74	49	71	52	73	—	—	78	88
17	92	95	48	70	48	70	48	70	48	70	52	73	—	—	84	91
22	90	94	56	82	52	73	51	72	52	73	—	—	—	—	86	92
Average	90.6	—	53	—	52 3	—	50.6	—	49.6	—	52	—	—	—	82.6	—
Rabbits																
3	76	85	45	62	44,5	61	43	59	44,5	61	49	66	—	—	67	80
6	83	72	38,5	53	41,5	57	44	60	41,5	57	41	56	—	—	67	80
16	78	86	47	64	41,5	57	38,5	52	39	53	38,5	52	39,5	54	72	83
20	80	87	51	68	42	58	40	55	45,5	62	38,5	52	45	61	65	79
28	80	87	40	55	39	53	41	56	42	58	40	55	—	—	67	80
Average	79.4	—	44.3	—	42.1	—	42.1	—	43.1	—	41.4	—	42.2	—	67.6	—

The results of experiments (mean data from repeated experiments) are presented in Table 1.

Table 1 shows both the direct readings on the scale of the apparatus and the percentage saturation determined by the use of conversion curves (see Fig. 1, a and b).

As can be seen from Fig. 2, a, "elevation" was accompanied by a regular drop in the oxygen saturation of the blood.

Having reached 57% during the first minute of being at an "altitude" the oxygen saturation rose to 60% after 3 minutes, and at the 5th minute was already 68%. After a brief drop to 62% it then again showed an increase and reached 72% at the 15th minute. The return to normal pressure was accompanied by a growing increase of saturation.

Figure 2 shows an example of the lowering of oxygen saturation of arterial blood in a rabbit. In this experiment a stepwise drop of saturation was observed during "elevation" to an "altitude" and certain fluctuations during the stay at the "altitude". These phenomena were determined by the frequent vigorous movements of the animal during that time. At the same time in this case too an increase of saturation from 55 to 58% was observed after being at the "altitude" for 15 minutes.

On returning to ordinary conditions the saturation reached the original values.

These experiments showed that in healthy, unoperated animals there was a decrease of saturation of arterial blood with oxygen when the atmospheric oxygen content was lowered; the dynamics of this decrease varied from animal to animal.

The next series of experiments was carried out on animals subjected to preliminary denervation of the carotid sinus zones. The degree of oxygen saturation of arterial blood prior to "elevation" was maintained at 90% in cats and 80% in rabbits.

Considerable diminution of saturation developed during the "elevation" and during the whole period of exposure to conditions corresponding to the experimental "altitude"; the values reached were 51% in cats and 41% in rabbits. During the return to ordinary conditions there was a gradual rise in the saturation as the atmospheric pressure approached normal.

At the same time in the case of all the operated animals the return to ground level conditions was not accompanied by restoration of the initial values of saturation; these remained lower, fluctuating between 78-86% in cats and 64-72% in rabbits during the 7-10 minutes of observation (Table 2).

It should be noted that changes in the degree of saturation may sometimes depend on the individual peculiarities of the experimental animals.

Examples of individual observations are given in Fig. 3,a and b. These show that an operated animal (cat No. 22) exhibited a drop of saturation to 51% which was maintained, approximately, in the course of the whole exposure to "altitude". During the "descent" the saturation showed a gradual increase, but during 5 minutes' observation following the "descent" (under normal conditions) it had not reached the original value, remaining at the level of 82-86% (Fig. 3, a).

A more rapid drop in saturation was observed in the case of rabbit No. 28 (Fig. 3, b): the saturation dropped from the original value of 80% to 41% as early as the first minute on reaching the "altitude" and remained at that level without appreciable deviations during all the time that the animal was exposed to those conditions. During the "descent" the saturation increased gradually but only reached 67% on return to normal atmospheric pressure (at the 7th minute of observation).

The results obtained provide evidence of more profound hypoxemia under conditions of reduced partial pressure of oxygen in animals with denervated carotid sinus zones than in healthy, unoperated animals. It is also characteristic that whereas in the former case the saturation remained almost stationary during the whole period of exposure to "altitude" conditions, in the latter case it exhibited a tendency to growing increase.

There is no doubt that oxygen starvation elicits compensatory mechanisms in the healthy animal which diminish the effect of factors unfavorable for the organism. Deprivation of the organism of interoceptive stimuli from the powerful reflexogenic carotid sinus zones causes marked disturbance of these compensatory mechanisms and consequently decreases the ability of the animal to counteract to some extent the oxygen

lack in the surrounding atmosphere. The delay in restoration of oxygen saturation of the blood upon return to ordinary conditions also indicates disturbance of normal compensatory reactions.

Taking into account the role of the carotid sinus zones in regulation of respiration it may be supposed that the more profound drop of saturation as well as the absence of compensatory saturation under "altitude" conditions observed in animals with denervated carotid sinus zones depend chiefly on disturbances of respiration.

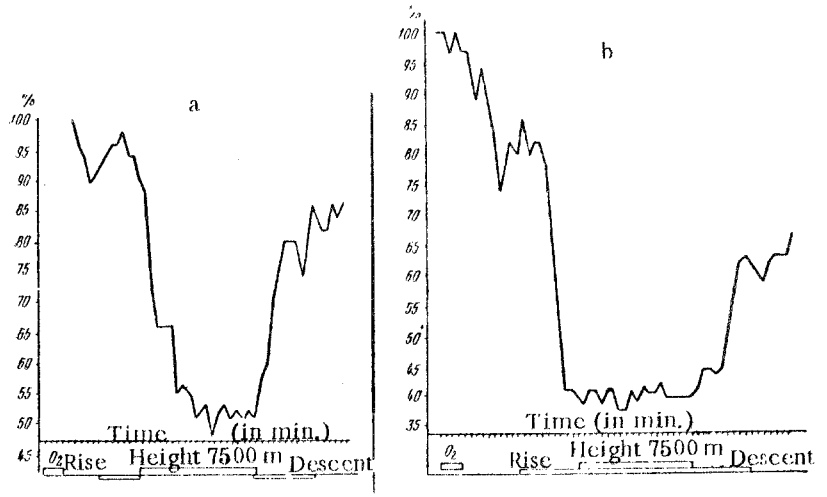

Figure 3. Dynamics of oxygen saturation of arterial blood. a) in cat (No. 22) with preliminary denervation of carotid sinus zones, b) in rabbit (No. 28). Records as in Fig. 2.

The degree of oxygen saturation of arterial blood at reduced partial pressures of O_2 in the inspired air depends to a considerable extent on the normal functioning of the carotid sinus reflexogenic zones which ensure compensatory reactions to oxygen starvation.

SUMMARY

Studies were made of the oxygen saturation in arterial blood in animals during exposure to 7500 m in a chamber. The study was carried out after the photoelectrical method by means of continous oxyhemometry in rabbits and cats with denervation of carotid sinus zones, as well as in controls. In the controls the saturation diminished to 55-62% and increased somewhat after 8-10 minutes' exposition to "altitude". In the experimental animals the diminution of oxygen saturation was more pronounced, reaching 40-50% and remained within this range during the whole period of exposure.

The experiments demonstrated that the dynamics and the degree of oxygen saturation of arterial blood in case of hypoxia depend on the function of the carotid sinus zones.

LITERATURE CITED

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