SECTION 3

RETINAL VASCULAR RESPONSE TO OXYGEN AT INCREASED PARTIAL PRESSURES

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Normal retinal arteries and veins constrict when the concentration of inspired oxygen rises and dilate when it falls.[1,2] In the immature retina, vasoconstriction due to chronic hyperoxia is followed by irreversible changes, such as obliteration of the vessels.[3,4] Adults breathing 100% oxygen at sea level show a 10.5 to 37.7% decrease in the caliber of retinal vessels.[1,5] The degree of constriction, which is more marked in the veins, is substantially complete within five minutes after passing from breathing air to oxygen at one atmosphere of pressure.[5,6] At the same time, no untoward opthalmologic symptoms or signs have developed in subjects breathing 100% oxygen at sea level for 4 to 24 hours.[6,7] However, inhalation of 100% oxygen at three atmospheres has resulted in a striking reversible impairment of vision in adults after four hours.[8] It has been suggested that the vasoconstriction in the eye in response to oxygen may serve a defensive purpose to protect the tissues from too high a concentration of oxygen.[1,9]

METHOD

A Nikon Fundus camera, using Kodak Tri-X Pan black and white film, was utilized to obtain retinal photographs of the six experimental subjects while breathing air at sea level, during the period of pre-oxygenation with 100% oxygen at sea level prior to ascent to altitude, 5 - 30 minutes after ascent to 27,000 ft on 100% oxygen, and after the subjects had been at altitude, breathing 100% oxygen for 19 days. The pupil of the test eye was dilated with tropicamide (Mydriacyl 1.0% Alcon) prior to each study. The 35 mm film was magnified 15 times on a glass screen using an IBM Microfilm Reader, and the larger retinal vessels were measured with a caliper and steel rule with 1/64 inch divisions.

The same three arteries and veins were measured on each photograph. Easily recognizable points on both veins and arteries were selected using the optic disc or a prominent A-V crossing as a reference. The diameter of the optic disc was the same in all enlargements, thus insuring that any changes noted were not due to differences in the focus or the distance at which the pictures were taken. Mean values were obtained for the three arteries or veins measured and the percent change from the control photographs was calculated (Table 3-1).

RESULTS AND DISCUSSION

Retinal photographs taken after the subjects had been breathing 100% oxygen at sea level for 5 to 30 minutes, show a decrease of approximately 17% in the caliber of the arteries and 20% in the veins, see Figure 3-1. Five to 30 minutes after the

ascent to 27,000 ft while breathing 100% oxygen, there was only a 6 to 8% decrease in the diameter of retinal veins and arteries. This degree of decrease remained essentially the same after 19 days at altitude on 100% oxygen.

There appears to be a direct correlation of the degree of vessel constriction to the oxygen tension of arterial blood.[6,10] Smaller vessels decrease disproportionally more than larger ones,[9] and thus the original diameter of the vessel has to be considered. This may in part account for the different values of retinal vessel caliber in response to oxygen as reported by various investigators.

The decrease in the diameter of retinal vessels is directly related to the decrease in circumference, however, without further studies, it would be difficult to attempt to correlate the diameter changes with changes in vascular resistance, and hence in the blood flow. It appears that the increase in blood oxygen transport during hyperbaric oxygenation more than compensates for the reduction in retinal blood flow due to vasoconstriction. This is evidenced by the fact that the color of blood in the veins changes to approximate that of the arteries[1,10] and that hyperbaric oxygen preserves vision for long periods of time during retinal ischemia.[11,12]

Vasoconstriction in response to increased partial pressures of oxygen may not be limited to the retina. It has been demonstrated that cerebral blood flow in man decreases by about 12% when 100% oxygen is breathed at one atmosphere and up to 24% at two atmospheres pressure.[13,14,15] Moreover, this vascular response to hyperoxia may be a general or a systemic one. An increased arterial blood oxygen tension, even at one atmosphere, will increase peripheral vascular resistance and decrease the cardiac output and heart rate.[16,17] The stroke volume and mean blood pressure do not change, however.

CONCLUSION

The fundus oculi offers a unique opportunity for the observation of alterations in vessel caliber during changes in arterial gas tensions. Measurements from retinal photographs are a convenient way of assessing such changes. Experiment results show that both retinal arteries and veins decrease progressively in size as arterial oxygen tension is increased.

Certain questions may be raised with respect to future investigations:

1. Is there a linear relationship between the caliber of retinal blood vessels and the partial pressure of inspired oxygen?

2. Does the retina have an autoregulatory mechanism for the control of its circulation; are retinal vessels particularly sensitive to oxygen, or is vasoconstriction a general response to hyperoxia?

3. Is the vasoconstriction due to a direct response to the increase in oxygen pressure, certain metabolic changes in the tissues, or to a homestatic mechanism to maintain tissue oxygen levels within fairly close limits and thus mitigate against possible deleterious effect of hyperbaric oxygen?

4. Is this effect due to local action of a chemical factor on the nervous cells or smooth muscle, or is the response mediated through certain neurohumeral mechanisms?

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TABLE 3-1

PERCENT CHANGE IN DIAMETER OF RETINAL ARTERIES AND VEINS BREATHING 100% OXYGEN AT SEA LEVEL AND AT SIMULATED ALTITUDE OF 27,000 FT.

	100% O_2 at sea level, 5 - 30 min	100% O_2 at 27,000 ft, 5 - 30 min	100% O_2 at 27,000 ft, 19 days
		ARTERIES	
SUBJECT			
1	-12.72%	-7.47%	-10.50%
2	-23.88%	-9.88%	-13.22%
3	-19.44%	-9.25%	- 5.55%
4	-11.42%	-2.38%	+ 2.38%
5	-13.46%	+3.03%	- 3.70%
6	-20.19%	-10.65%	- 5.12%
MEAN	-16.68%	-7.88%	- 6.74%
		VEINS	
SUBJECT			
1	-19.34%	-10.71%	- 8.92%
2	-23.88%	-9.88%	-13.22%
3	-13.80%	-5.12%	- 2.00%
4	-19.36%	-5.55%	- 2.22%
5	-20.60%	-4.60%	- 7.35%
6	-20.74%	-5.12%	- 7.21%
MEAN	-19.55%	-5.87%	- 5.31%

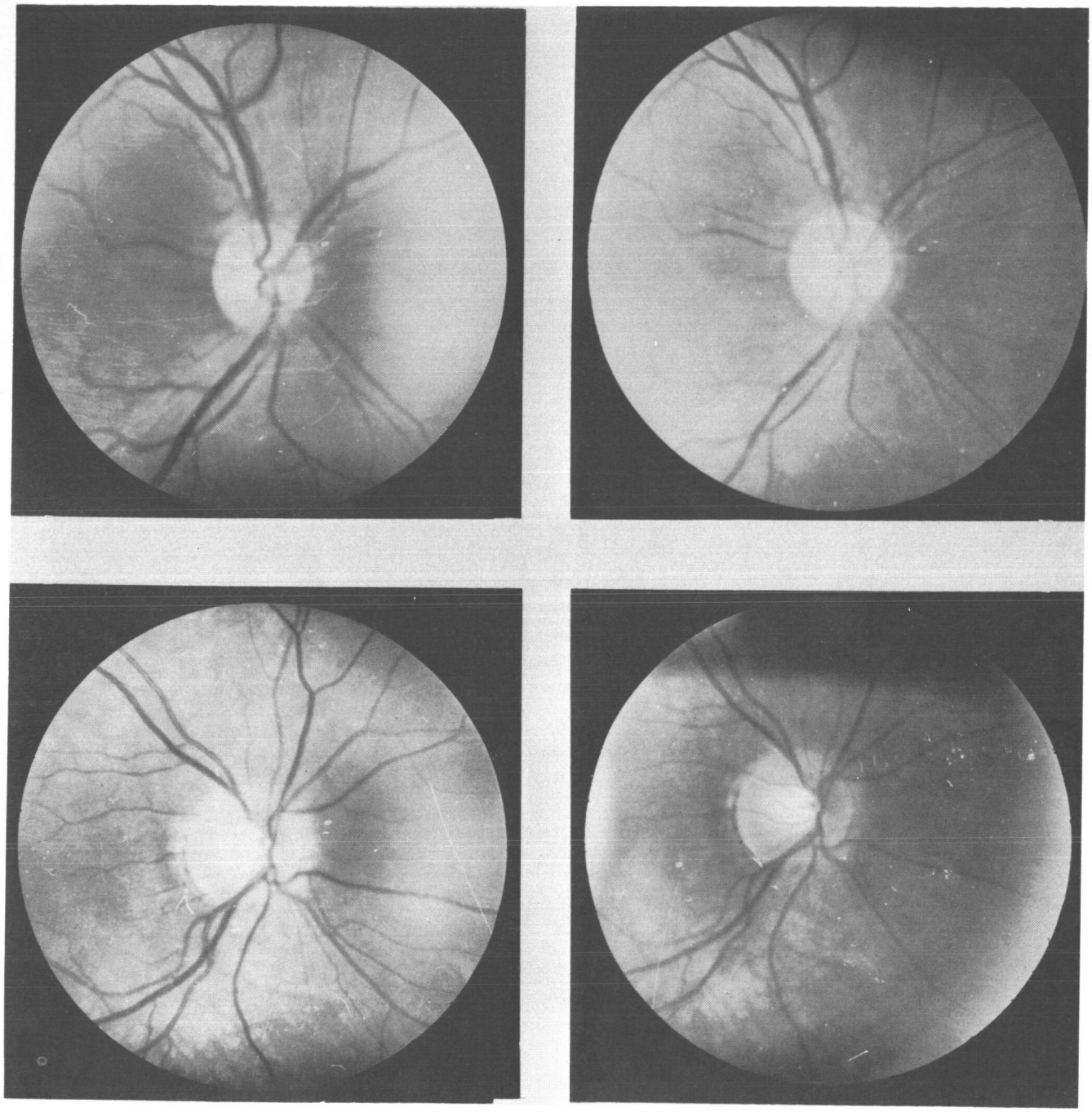

Figure 1 Retinal photographs of two subjects before (left) and while breathing 100% oxygen at sea level (right) showing a decrease in caliber of vessels.

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