JPRS: 4381

6 February 1961

THE METHODOLOGY OF INVESTIGATING GAS METABOLISM IN THE INSPIRATION OF LARGE CONCENTRATIONS OF OXYGEN

-USSR-

By V. P. Bezugliy

Distributed by:
OFFICE OF TECHNICAL SERVICES
U. S. DEPARTMENT OF COMMERCE
WASHINGTON 25, D.C.

U. S. JOINT PUBLICATIONS RESEARCH SERVICE
1636 CONNECTICUT AVENUE, N. W.
WASHINGTON 25, D. C.

JPRS: 4381

CSO: 1414-S

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[Following is the translation of an article entitled "K metodike issledovaniya gazoobmena pri vdykhanii bol'shikh kontsentratsiy kisloroda" (English version above) by V. P. Bezugliy in Laboratornoye Delo (Laboratory Work), Vol VI, No 5, Moscow, 1960, pages 22-24.]

Oxygen therapy is finding greater clinical application in internal diseases. The mechanism of large oxygen concentration effects on a healthy, as well as diseased organism, is in need of further study. It is particularly essential to study the oxygen consumption and CO_2 excretion changes in the inspiration of large concentrations of oxygen.

The therapeutic concentration of oxygen in the oxygen tent is, as is known, 50-60%. However, using a Holden gas analysor, it is only possible to examine oxygen concentrations not exceeding 40%, and practically, in the range of 30%.

We have proposed a means of determining large oxygen concentrations (60%) by using a Holden analysor and have developed formulae for calculating oxygen consumption and CO_2 excretion.

The investigations are conducted in the following manner: Into an exygen tent, along with the test subject, is placed a mask with a valve from which a hose leads to a three-way stop-cock, and then to a "Douglas" bag, located outside the tent. The tent is tightly closed and an oxygen concentration of 50% and higher is created within. The test subject, after 20-30 minutes in the tent, puts on the mask and for five minutes breathes the tent air with the high oxygen concentration, exhaling through the valve and hose into the bag. The three-way stop-cock is closed and the mask is taken off.

Usually, the test air (1 l)is taken from the bag into a ball chamber, the remaining air is let through gas meters, and the volume of air expired for the five minute period, is determined. To this volume is added one liter of air taken for the test sample in the ball chamber.

For calculating the average oxygen concentration in the exhaled air, into another ball chamber is stored 3/4 liter of air from the tent, before and after taking the exhaled air.

In order to examine the air under study with the Holden apparatus, the air had to be mixed with exterior air in set proportions to decrease the oxygen concentration. For this, 12 cc of room air are placed into the burette of the gas analyzor, and then eight cc of the examined air (expired or inspired) is gradually allowed into the burette from the ball chamber.

The oxygen concentration in the mixture is held below 40%, and this makes it possible to examine it with the Holden apparatus.

The calculation is made in the following manner: If the percent of oxygen in the mixture (eight cc of tent air and 12 cc of exterior air), obtained in the gas analyzor is equal to Z, the percent of oxygen in the tent equal to X, and the percent of oxygen in the exterior air equal to Y, we then have:

$$\frac{8.X\%}{100} + \frac{12.Y\%}{100} = \frac{20.Z\%}{100} \qquad \text{(I)}$$

The exact same calculation is made for CO_2. If the percent of CO_2 in the mixture obtained in the gas analyzor is equal to K, the percent of CO_2 in the tent air equal to M, and in the exterior air equal to N, we have:

$$\frac{8.M\%}{100} + \frac{12.N\%}{100} = \frac{12.K\%}{100} \qquad \text{(II)}$$

Eight cc of expired air and 12 cc of external air is also taken into the burette of the gas analyzor. If the percent of O_2 in the mixture is equal to Z, the percent of CO_2 equal to K_1, the percent of O_2 in the expired air equal to X_1, and in the external air equal to Y, the percent of CO_2 in the expired air equal to M_1, and in the external air equal to N, we have:

$$\text{for } O_2 \quad \frac{8.X_1\%}{100} + \frac{12.Y\%}{100} = \frac{20.Z_1\%}{100} \qquad \text{(III)}$$

$$= \quad \text{for } CO_2 \quad \frac{8.M_1}{100} + \frac{12.M\%}{100} = \frac{20.k_1\%}{100} \qquad \text{(IV)}$$

Since Y, i.e. the percent of oxygen in the external air, is constant for a given interval of time, subtracting equation III from equation I, we get

$$\frac{8.X}{100} - \frac{8.X_1}{100} = \frac{20.Z}{100} - \frac{20.Z_1}{100}; \quad \frac{8.(X-X_1)}{100} = \frac{20.(Z-Z_1)}{100}$$

$$X-X_1 = \frac{5}{2} \quad (Z-Z_1)$$

where $X-X_1$ is the difference in the concentration of oxygen in the inspired and expired air, and where $Z-Z_1$ is the difference in the concentration of oxygen in the mixture, i.e. the known quantity.

Knowing the difference of the oxygen concentration (in percent) between the inspired and expired air, and the magnitude of pulmonary ventilation, it is possible to determine the amount of oxygen consumption per unit time. Oxygen consumption per one minute = $LV_0 \cdot (Z-Z_1) \cdot \frac{5}{2} \cdot 10$ (LV_0 is pulmonary ventilation, corresponding to normal conditions: temperature 0^o, pressure 760mm Hg)

The above quantity is multiplied by 10 in order to convert liters into cubic centimeters (multiplying by 1000, and dividing by 100, since the difference is expressed in percent)

Subtracting equation II from equation IV, we get:

$$\frac{8.M_1\%}{100} - \frac{8.M\%}{100} = \frac{20.k_1\%}{100} - \frac{20.K\%}{100}; \quad \frac{8(M_1 - M)}{100} = \frac{20\ (K_1 - K)}{100}$$

$$M_1 - M = \frac{5}{2}\ (K_1 - K)$$

where $M_1 - M$ is the difference in the CO_2 concentration in the expired and inspired air, and $K_1 - K$ is the difference in the concentration of CO_2 in the mixtures, and from this, the CO_2 excretion per minute = $LV_0\ (K_1 - K)\ 5/2 \cdot 10$.

With the aid of the suggested formulae, a determination was made of absorbed oxygen and excreted CO_2, in patients with hypertension, per minute for 30 minutes, in an oxygen tent at an oxygen concentration of 40 - 50%.

An example of such a calculation is the following: Patient G, suffering from third degree hypertention, for a five minute period, expired through a mask 37.3 l of air (including the test air allowed into the ball chamber). Pulmonary ventilation for one minute at a room temperature of 20^o and barometric pressure of 748 mm Hg, was 6.608 l (LV_0). The oxygen concentration in the mixture of external air (12 cc) and tent air (8 cc) was 22.9%, and CO_2 was 0.25%. The O_2 concentration in the mixture of external air (12 cc) and expired air (8 cc) was 21.7%, the CO_2 concentration was 1.25%.

From this, the oxygen consumption = $LV_0 \cdot (Z - Z_1) \cdot 5/2 \cdot 10$ or $6.6080 \cdot (22.9 - 21.7) \cdot 5/2 \cdot 10 = 198.2$ cc

The CO_2 excretion is analogously determined:

CO_2 excretion = $LV_0 \cdot (K_1 - K) \cdot 5/2 \cdot 10 = (1.25 - 0.25) \cdot 5/2 \cdot 10 \cong 165.2$ cc.

Editor's note: The editor places the present article in connection with the fact that oxygen therapy is being widely used clinically, and attempts are being made to study the mechanism of breath= ing in high concentrations of oxygen. In addition, high concentrations of oxygen are essential to breathing in certain types of work, such as for example, in diving suits, and in underwater chambers of small volume.

The described method is based on the principle of using atmospheric air as the test sample. However, nitrogen, remaining in the Holden apparatus pipette from a previous analysis, is usually used in laboratories conducting gas analyses of air with high concentrations of oxygen (See, for example, the direction of R. P. Ol'yanska and L. A. Isaakyan "Metody issledovaniya gasobmena u cheloveka i zhivotnykh" -- "Research Methods of Gas Metabolims in Man and Animals", Medgiz (State Medical Publishing House), 1959, page 97).

However, the method adopted by the author can also be useful for persons studying gas metabolism under the given conditions.

The reader should consider that the peculiarities of breathing and gas metabolism in an oxygen tent, depend not only on high concentrations of oxygen, but on high CO_2 content as well. The concentration of the latter, depending on the test volume, degree of hermiticity and speed of oxygen entry into the tent, may reach magnitudes exceeding 1%. This is apparent from the example cited by the author. In addition, it must be considered, that in high concentrations of oxygen (greater than 40%), there may develop in man an acidosis, accompanied by a fall in the blood alkaline reserve and a compensatory excretion of CO_2 in the expired air, in greater than normal amounts.

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