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

-USSR-

By V. P. Bezugliy
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[FOLLOWING IS THE TRANSLATION OF AN ARTICLE ENTITLED "K METODIKE ISSLEDOVANIYA GAZOOBZACENI PRI VYKHANII BOL'SHIX KONTENTSATSIY KISLORODA" (ENGLISH VERSION ABOVE) BY V. P. BEZUGLYI 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 CO₂ 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 analyser, 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 analyser and have developed formulae for calculating oxygen consumption and CO₂ excretion.

The investigations are conducted in the following manner:
Into an oxygen 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 analyzer, 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 analyzer 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:

\[
\frac{8.X}{100} + \frac{12.Y}{100} = \frac{20.2}{100} \tag{I}
\]

The exact same calculation is made for \( \text{CO}_2 \). If the percent of \( \text{CO}_2 \) in the mixture obtained in the gas analyzer is equal to \( K \), the percent of \( \text{CO}_2 \) in the tent air equal to \( M \), and in the exterior air equal to \( N \), we have:

\[
\frac{8.M}{100} + \frac{12.N}{100} = \frac{12.K}{100} \tag{II}
\]

Eight cc of expired air and 12 cc of external air is also taken into the burette of the gas analyzer. If the percent of \( \text{O}_2 \) in the mixture is equal to \( Z_1 \), the percent of \( \text{CO}_2 \) equal to \( K_1 \), the percent of \( \text{O}_2 \) in the expired air equal to \( X_1 \), and in the external air equal to \( Y_1 \), the percent of \( \text{CO}_2 \) in the expired air equal to \( M_1 \), and in the external air equal to \( N_1 \), we have:

\[
\begin{align*}
\text{for } \text{O}_2 & \quad \frac{8.X_1}{100} + \frac{12.Y}{100} = \frac{20.Z_1}{100} \tag{III} \\
\text{for } \text{CO}_2 & \quad \frac{8.M}{100} + \frac{12.N}{100} = \frac{20.K_1}{100} \tag{IV}
\end{align*}
\]

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

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

\[
X - X_1 = \frac{5}{2} (Z - Z_1)
\]
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 = \( LV_0 \cdot (Z - Z_1) \cdot \frac{5}{10} \) (where \( LV_0 \) is pulmonary ventilation, corresponding to normal conditions: temperature 0°C, pressure 76cm 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:

\[
\frac{8.4\%}{100} - \frac{8.1\%}{100} = \frac{20.1\%}{100} - \frac{20.1\%}{100}; \quad \frac{8(M_1 - M)}{100} = 20 \left( \frac{K_1 - K}{100} \right)
\]

\[
K_1 - K = \frac{5}{2} \left( \frac{K_1 - K}{100} \right)
\]

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 = \( LV_0 \left( \frac{K_1 - K}{100} \right) \cdot \frac{5}{2} \cdot 10 \).

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 hypertension, 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°C 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 \( CO_2 \) 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 = \( LV_0 \cdot (Z - Z_1) \cdot \frac{5}{2} \cdot 10 \) or 6.6080 \( \cdot (22.9 - 21.7) \cdot \frac{5}{2} \cdot 10 = 198.2 \) cc

The \( CO_2 \) excretion is analogously determined:

\[ CO_2 \text{ excretion} = LV_0 \cdot (K_1 - K) \cdot \frac{5}{2} \cdot 10 = (1.25 - 0.25) \cdot \frac{5}{2} \cdot 10 \approx 165.2 \text{ cc} \]

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 breathing 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 gaseboema u cheloveka i zhivotnykh" — "Research Methods of Gas Metabolism 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 CO₂ content as well. The concentration of the latter, depending on the test volume, degree of hermeticity 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 CO₂ in the expired air, in greater than normal amounts.