DETERMINATION OF THE ALVEOLAR DEAD SPACE

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A method of obtaining the alveolar dead space (ADS), the part of the functional dead space (FDS) that is most difficult to determine, is suggested. The method of determination is based on the difference in the CO₂ concentration in the venous blood flowing to the lungs for oxygenation under quiet breathing conditions and the CO₂ concentration in alveolar portions of the expired air after breath holding for 10 sec at the level of ordinary inspiration. The mean volume of ADS (VₐDS) as a percentage of the alveolar part of the respiratory volume for 20 healthy subjects in the sitting position and for 12 of them in recumbency, with the corresponding sampling errors and dispersions, is: VₐDS (sitting) = 8.0 ± 1.5% (P = 0.95); VₐDS (recumbency) = 5.0 ± 1.7% (P = 0.95). It is suggested that first, the effectiveness of utilization of the inspired air for ventilation of the lungs can be judged on the basis of the FDS determined by the newly developed method; second, that ADS be determined for the diagnosis of pulmonary embolism; and third, that shunting of the pulmonary blood flow be estimated from the difference between the value found for FDS by Bohr's equation and for FDS determined by the suggested formula.

KEY WORDS: Ventilation of the lungs; functional dead space; anatomical dead space; alveolar dead space.

The functional dead space (FDS) is a measure of the degree of ineffectiveness of utilization of air entering the lungs and respiratory passages, in the gas exchange with the blood. It consists of two parts: anatomical and alveolar. The anatomical part is accounted for by inspired air entering the respiratory passages from which it is exhaled without having taken part in the gas exchange with the blood. This volume can be determined by Bohr's equation, as suggested for calculation of the anatomical dead space (ANDS) or planimetrically from the single expiration curve [1]. If the dead space is found planimetrically allowing for the alveolar gradient of the single expiration curve, the value obtained will include not only ANDS, but also part of the alveolar dead space (ADS), due to the presence of laminar heterogeneities of gas composition in the lungs as a result of the insufficiently uniform diffusion mixing of the inspired and alveolar air [2-5]. The fraction of ADS due to laminar heterogeneities can conveniently be found together with ANDS. The alveolar part of FDS which must be determined, and which will be considered from now on, consists of the volumes of inspired air entering the unperfused regions of the lungs at the end of inspiration (situation a) and entering the regions where a blood supply exists and may be within normal limits, but where the permeability of the lung membrane is disturbed (situation b). In these regions of the lungs gas exchange between air and blood is absent. Partial disturbances of the blood flow or diffusion of gases through the membrane also lead to some increase in ADS. Situations a and b are illustrated schematically in Fig. 1, where another case (case c), corresponding to lung volumes in which ventilation, blood flow, and gas exchange through the lung membrane are not disturbed, is also represented.

The method of determining ADS suggested in this paper is based on the difference between the CO₂ concentration (cCO₂) in the venous blood and cCO₂ measured in alveolar portions of the expired air after breath holding at the level of ordinary inspiration, for this difference is determined by the same causes as ADS existing in the lungs.

Fig. 1. Gas exchange in lungs represented schematically by 3 alveolar volumes: a) ventilation present, blood flow absent; b) ventilation and blood flow both present, gas exchange through lung membrane absent; c) normal gas exchange. I) Volume of inspired air entering regions a and b of ADS at inspiration; 2) AnDS; 3) effective alveolar respiratory volume entering region c and taking part in gas exchange with blood.

EXPERIMENTAL METHOD

The value of cCO₂ was obtained by means of a capnograph (from Godart, Holland). The investigation began after the patient had rested. The subject was connected to the instrument and breathed air until the instrument began to record stable values of cCO₂ from one expiration to another. Then, in accordance to instruction, the patient took an ordinary inspiration and held his breath for 10 sec; in expiration cCO₂ was determined in the alveolar portion Fₐ. The breath holding was chosen on the basis of the following requirements: A time interval of 10 sec is sufficient to allow equalization of cCO₂ between the alveolar air and venous blood flowing to the lungs in the regions represented in situation c (Fig. 1); this interval is shorter than the blood recirculation time and, consequently, over this time interval no changes take place in the composition of blood flowing to the lungs. Satisfaction of the first demand was confirmed by the fact that in healthy subjects the gas concentration in the last portions of expired air showed little change with a change in breath holding from 10 sec to the blood recirculation time.

The true value of cCO₂ in venous blood flowing to the lungs for oxygenation of Fᵥ was determined by the rebreathing method in two stages. The subject first produced a working mixture for himself with cCO₂ close to the venous level. After resting, the patient was connected to the bag containing the working mixture and, in accordance with instruction, took several (5-7) breaths with respiratory volumes (RV) close to the vital capacity of the lungs in the course of 15-20 sec. During this period, as a rule, recirculation of the blood did not take place but equilibrium was established between the alveolar gas and the blood. Otherwise the investigation was carried out in three stages (the third stage similar to the second)

When the time arises during rebreathing when no CO₂ is exchanged between the alveolar air and blood, the gas concentration in the alveolar air is known to be higher than its true concentration in the venous blood. However, it has been shown that this difference is small under quiet breathing conditions [6], when it can be disregarded. This was taken into account when Fᵥ was determined by the rebreathing method. This value can also be found by direct measurement in mixed venous blood.

The difference between F₁₀ and Fᵥ obtained in this way is due to the same causes as ADS. In fact, during the period of breath holding cCO₂ in region c is equal to Fᵥ. However, in expiration the CO₂ expelled from region c is diluted with air expelled from regions a and b,