A METHOD OF DETERMINING ARTERIAL pCO_2 IN PERSONS WITH DISTURBED EXTERNAL RESPIRATORY FUNCTION

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A simple method of determining arterial pCO_2 in hypercapnic states has been developed and tested. It consists essentially of determining the arterial pCO_2 at the end of submaximal breath holding.

One of the most important indices of external respiratory function and the acid-base balance of the blood is the partial pressure of carbon dioxide in the arterial blood (arterial pCO_2). Under a wide variety of physiological and pathological states the need arises for a rapid and reliable method of determination of the arterial pCO_2 as an index of the adequacy of the pulmonary ventilation. Direct investigation of the blood gases is an acute but complicated method, for it is not always easy, by any means, to obtain blood by arterial puncture, and the determination of the CO_2 tension in arterial capillary blood requires an expensive apparatus and is wasteful of the time of trained personnel. It is much more convenient to determine the arterial pCO_2 from the value of the alveolar pCO_2. In the healthy person, the difference between these two values is in fact extremely small and in many cases it is virtually nonexistent.

However, even in the healthy subject it may be difficult under many conditions to obtain alveolar air. In persons with various types of disturbance of external respiratory function (variation of the ventilation-perfusion ratio, with intra- and extrapulmonary shunts and with marked disturbances of diffusion) the position is complicated by the variation in composition of different samples of expired air and by the difference which exists between the CO_2 tension in the arterial blood and in the alveolar gas in these cases [1, 2].

During rebreathing in a closed system of low volume equilibrium must be rapidly attained between the partial pressures of carbon dioxide in the alveolar air and in the mixed venous blood. This equilibrium can be detected and recorded by means of low-inertia gas analyzers of the Capnograph, GUM-2, and GUM-3 types or determined by rapid analyzers of the GUKh-1 type [3-7]. Modern methods of indirect determination of pCO_2 in mixed venous blood and, after appropriate calculations, in arterial blood, are based on this principle [8, 10], which enables the minute volume of the circulation to be calculated by the Fick principle. However, the rebreathing procedure is sometimes difficult for the subject undergoing the test and it may even be impossible if marked disturbances of external respiratory function are present. For that reason, at the suggestion of Academician of the Academy of Medical Sciences of the USSR, B. E. Votchal, since 1965 a simpler method of determining the partial pressure of carbon dioxide in the arterial blood from its pressure in the alveolar air, obtained from the final portion of the expired air after voluntary submaximal breath holding in inspiration, has been developed. A special series of experiments showed that submaximal breath-holding in inspiration is optimal, it presents no difficulty for the patient (without the Valsalva's maneuver), and it varies individually in duration. The time of breath-holding varies within wide limits depending on the category of disturbance of pulmonary function (6-8 sec in cases of marked, purely restrictive disturbances, e.g., in Hamman-Rich disease, to 40-60 sec in marked obstructive syndromes with a high residual lung volume).

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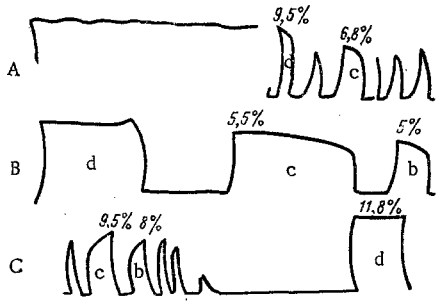

Fig. 1.

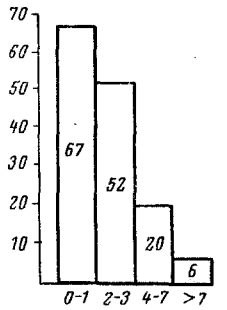

Fig. 2.

Fig. 1. Capnogram of a patient: A) with a marked obstructive syndrome and hypercapnia (arterial pCO_2 60 mm Hg). Comparison with Collier's method: on the left – plateau during rebreathing (9.5% CO_2), on the right – after voluntary submaximal breath-holding (9.5% CO_2); B) in normocapnia and moderate obstructive disturbances (arterial pCO_2 41 mm Hg); C) in marked hypercapnia (arterial pCO_2 80 mm Hg); b) ordinary expiration; d) expiration after voluntary submaximal breath-holding; numbers denote CO_2 concentration (in percent).

Fig. 2. Divergence between direct and indirect determination of arterial pCO_2. Ordinate, number of cases; figures beneath columns show differences in pCO_2 (in mm Hg).

The alveolar pCO_2 determined by this method is very close to pCO_2 of mixed venous blood. This is evidently because, when the volume of air in the lungs is comparatively small, a short time is sufficient for pCO_2 in the alveolar air to become equal to pCO_2 of the inflowing venous blood. The best way of determining carbon dioxide in the alveolar air after voluntary submaximal breath-holding is by means of the GUM-3 instrument or Capnograph. As a rule a plateau can be obtained on the capnogram after breath-holding as described above even when no such plateau can be obtained during ordinary deep expiration.

A reliable picture of the alveolar pCO_2 under the conditions associated with this method can also be obtained even by the use of such simple and cheap gas analyzers as the GUKh-1 and GUKh-2, although of course these methods are less accurate.

The technique has been constantly checked for its repetitiveness. Comparisons were made with Collier's method (rebreathing in a closed system incorporating a low-inertia gas analyzer – the Goddart, GUM-2, or GUM-3 Capnograph), and with a modification of Campbell's method (with a rapid analyzer of the GUKh-1 type). Agreement between the results was perfectly adequate as regards accuracy (Fig. 1). In 145 cases with various types of disturbance of external respiratory function this technique was compared with a parallel determination carried out on arterial blood by the micro-Astrup method (L. S. Shcherbakova and A. I. Kabakov). As Fig. 2 shows, the divergence as a rule does not exceed 3 mm Hg, so that the method can be used in all cases when it is essential to have a rapid estimate of the subject's condition as reflected in the arterial pCO_2.

Divergences of 4-7 mm Hg were found in 20 of the 145 cases, and in marked hypercapnia this could not be due to errors of inference. Only in six cases were divergences greater than 7 mm Hg, but this happened in patients with severe disturbance of the pulmonary circulation and high hyperventilation (embolism of branches of the pulmonary artery), in which any indirect determination gives only a highly approximate result. In these cases also the results of the determination agreed with those obtained by Collier's method.

The suggested method is easily reproducible, does not fatigue the patient, is not time-consuming for either subject or investigator, and it can be used in different situations and in persons with severe degrees of disturbances of external respiratory function of various kinds with sufficient accuracy for clinical purposes.

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