Evaluation of Tissue Oxygen Uptake Using the Anion Gap Parameter

G. M. Sakharova, V. A. Brazhnik, E. A. Gvozdeva, O. N. Makretskaya, and A. G. Chuchalin

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The possibility of using the anion gap, a parameter characterizing the electrolyte balance, for an evaluation of tissue oxygen uptake is studied. A reliable reverse linear dependence is found between the anion gap at rest and oxygen uptake at the onset of the anaerobic threshold, which allows the anion gap to be used for evaluating the efficiency of respiration as a whole and the involvement of compensatory mechanisms in patients with respiratory disorders. The anion gap parameter makes it possible to determine the adequacy of tissue oxygen uptake and tolerance for physical strain without exercise testing. The dynamics of this parameter reflects the changes in tissue oxygen uptake and tolerance for physical strain in the course of treatment.

Key Words: *anion gap; anaerobic threshold; tissue oxygen uptake; tolerance for physical strain*

Tissue oxygen uptake is the final stage in the respiratory chain. It is known that the disturbance of any stage of the respiratory chain may disrupt oxygen supply to the tissues [2] and, consequently, activate anaerobic mechanisms of tissue metabolism.

The adequacy of tissue oxygen uptake is currently evaluated using exercise testing by determining the anaerobic threshold (AT), i.e., the moment when anaerobic mechanisms kick in [1,5,6]. However, this method has certain limitations, since exercise testing is contraindicated in some patients.

Activation of the anaerobic mechanisms of energy production results in the accumulation of partially oxidized metabolites and a reduced tolerance for physical strain [4]. Thus, the adequacy of tissue oxygen uptake may be judged from the concentration of partially oxidized metabolites. To this end we used the anion gap (AG), a parameter which allows for the evaluation of the blood concentration of partially oxidized products: $AG=([Na]+[K])-([HCO_3]+[Cl])$ [3].

Research Institute of Pulmonology, Russian Ministry of Health and the Medical Industry, Moscow

AG increases in parallel with the concentration of partially oxidized products. We assumed that AG will sharply increase not only after the attainment of AT during physical exercise but even at rest. To verify this assumption we studied the relationship between the value of tissue oxygen uptake at the onset of AT, $VO_2(AT)$ and AG in the arterial blood at rest.

We studied the dynamics of AG in patients in the course of treatment in parallel with the dynamics of parameters traditionally used for evaluating the functional system of the lungs and blood oxygenation.

MATERIALS AND METHODS

The relationship between $VO_2(AT)$ and AG was studied in a group of 23 patients (20 men and 3 women). Four of them were healthy volunteers and 19 patients had various lung diseases: chronic bronchitis (12), bronchial asthma (2), chronic bronchitis and bronchial asthma (1), mucoviscidosis (1), pulmonary mycosis (1), and fibrosing alveolitis (2). The criteria for inclusion in the trial were: the ability to perform the bicycle test; 2) a normal electrolyte balance; 3) no infusion therapy.

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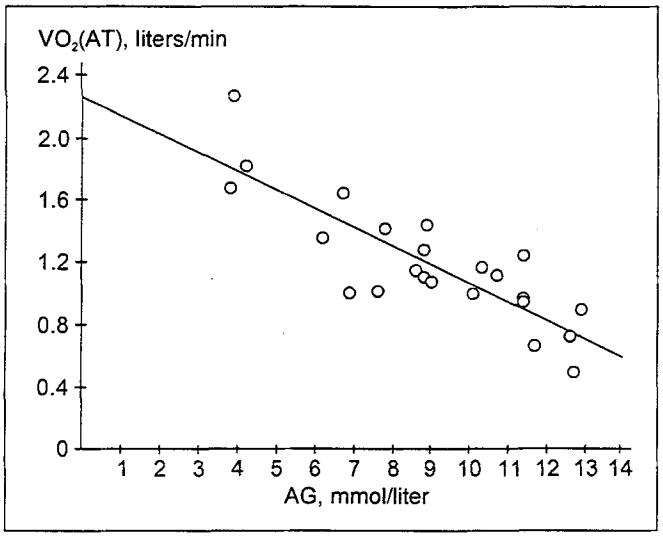

Fig. 1. Plot of VO_2(AT) and AG at rest.

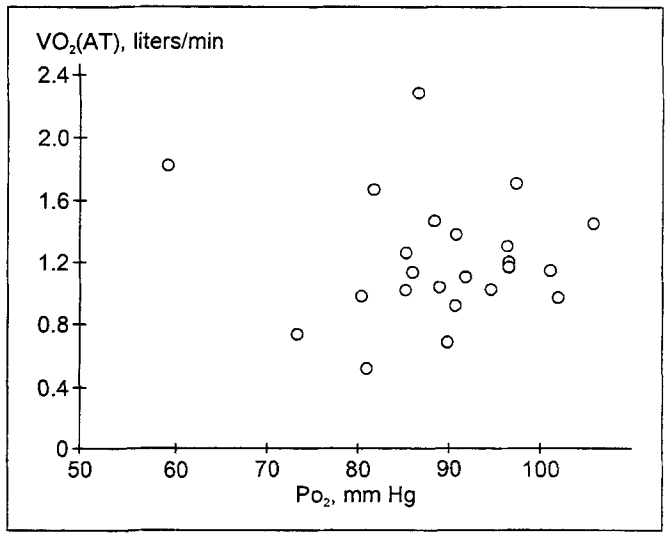

Fig. 2. Plot of VO_2(AT) and Po_2.

The dynamics of AG in the course of treatment was studied in 5 patients (3 men and 2 women, before and after treatment).

The respiratory function (spirometry and parameters of the flow-volume curve) was tested in all patients on a Masterlab analyzer (Erich Jaeger). For evaluation of the respiratory function the following parameters were used: forced vital capacity (FVC) and forced expiration volume for 1 sec (FEV1).

Arterial blood was drawn from the radial artery immediately before exercise testing and analyzed with a 288 Blood Gas System (Ciba Corning Diagnostics). The following parameters were used: partial oxygen pressure (Po_2), content of oxygen in the arterial blood (ctO_2), Na^+, K^+, Cl^-, HCO_3^-, and AG.

VO_2(AT) was measured on EOS Sprint and ER900 instruments (Erich Jaeger). The method of AT determination is described in detail elsewhere [4]. Physical load was delivered stepwise starting from 20 W with a subsequent 20 W increase every 3 min until the AT was attained, i.e., respiratory coefficient RQ=1. Oxygen uptake measured at this moment was VO_2(AT). The patient's state during exercise was monitored by measuring arterial pressure and heart rate.

In patients in whom the dynamics of AG was studied in the course of treatment, respiratory function was assessed and arterial blood was analyzed before and after treatment.

The relation between VO_2(AT) and AG of arterial blood at rest was evaluated using linear regression analysis. The reliability of linear regression was determined at $p<0.05$.

RESULTS

A strong correlation was revealed between the AG of arterial blood at rest and oxygen uptake corresponding to the anaerobic threshold VO_2(AT) (r=-0.83, $p<0.05$, Fig. 1).

Using the method of linear regression we obtained the following dependence: AG=16-5.93VO_2(AT). Evaluation of the regression coefficient confirmed the reliability of this dependence. Our findings suggest that in patients with high values of AG at rest AT during ex-

TABLE 1. Dynamics of Respiratory Indexes and Parameters of Arterial Blood in the Course of Treatment

№	Observation period	Age	FVC		FEV1		Po_2, mm Hg	ctO_2, ml/dl	AG, mmol/liter
			liters	%	liters	%			
1	before treatment	69	0.56	18.5	1.98	50.1	57.0	17.0	9.8
	after 14 days		0.68	22.4	1.94	49.2	54.9	19.0	8.0
2	before treatment	66	0.68	20.4	2.46	57.1	53.8	18.3	10.9
	after 14 days		0.72	21.6	2.33	54.1	56.2	17.7	7.5
3	before treatment	71	2.12	114	2.43	107	53.7	15.0	12.4
	after 27 days		2.44	115	2.88	109	81.1	16.9	5.2
4	before treatment	46	0.56	19.2	0.96	28.3	53.8	20.2	12.9
	after 14 days		0.88	30.2	1.8	53.2	64.7	20.6	3.9
5	before treatment	57	1.92	62.3	3.31	85.9	64.7	20.5	13.9
	after 13 days		2.20	71.3	3.60	93.4	85.4	20.7	4.4

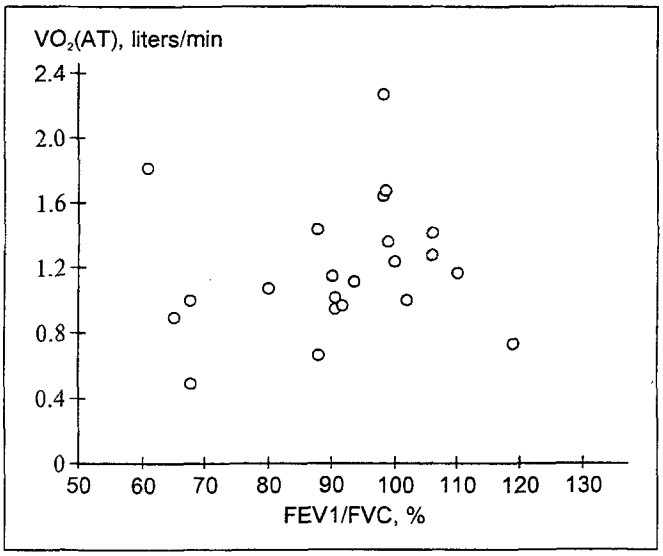

Fig. 3. Plot of FEV1/FVC and VO_2(AT).

ercise sets in at a lower VO_2(AT) value, which implies a reduced tissue oxygen uptake and lowered tolerance for physical strain. Thus, AG reflects the adequacy of tissue oxygen uptake and, consequently, the tolerance for physical strain and may therefore be used for the evaluation of these parameters along with VO_2(AT).

The fact that the experimental group included both patients with pulmonary diseases and healthy volunteers shows that the obtained relation between VO_2(AT) and AG represents a physiological dependence. However, AG can be said to reflect tissue oxygen uptake only if disturbances in electrolyte balance and renal pathology are ruled out and patients receive no infusion therapy.

We also studied the dependences between VO_2(AT) and Po_2 (Fig. 2) and FEV1/FVC (Fig. 3). No reliable dependence was found, which ties in with the fact that disturbances in one element of the respiratory chain may be compensated by others. Hence, parameters Po_2 and FEV1/FVC cannot be used for evaluating the adequacy of tissue oxygen uptake.

The dynamics of AG in the course of treatment is presented in Table 1. The improvement in the patients' state reflected by Po_2, ctO_2, FEV1, and FVC was seen to be accompanied by a drop of AG, which may indicate normalization of tissue oxygen uptake and an increase in the tolerance for physical strain.

Thus, the experiments demonstrated that AG reflects the adequacy of tissue oxygen uptake and tolerance for physical strain. A reliable linear dependence was revealed between AG of arterial blood and VO_2(AT), allowing this parameter to be used for gauging the efficiency of respiration as a whole and the involvement of compensatory mechanisms in patients with respiratory disorders. AG makes it possible to evaluate the presence of anaerobic mechanisms of tissue respiration without exercise testing. The dynamics of this parameter reflects the changes in tissue oxygen uptake and tolerance for physical strain.

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