ANALYSIS OF RHYTHMS OF NIGHT BREATHING OF PATIENTS WITH BRONCHIAL ASTHMA BY METHOD OF LYAPUNOV

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Bronchial asthma is an acute or chronic disorder characterized by widespread and largely reversible reduction in the caliber of bronchi and bronchioles, due in varying degrees to smooth muscle spasm, mucosal edema, and excessive mucus in the lumens of airways. Cardinal symptoms are dyspnea, wheezing, and cough. Attacks or exacerbations may be induced by airborne allergens (molds, pollens, animal dander, dust mite and cockroach antigens), inhaled irritants (cold air, cigarette smoke, ozone), physical exercise, respiratory infection, psychological stress, or other factors [1]. Bronchial asthma is a serious global health problem. From 5% to 10% of persons of all ages suffer from this chronic airway disorder [2].

Types of bronchial asthma:

1. Bronchial asthma psychogenic-induced (BAPI). Asthmatic attacks are developed after emotional stress, mental shock or a stressful vital event.

2. Bronchial asthma non-psychogenic (BANP). Asthmatic attacks are often preceded by allergic rhinitis, urticaria, eczema and physical factors (cold and temperature difference). Psychological factors were not noticed to influence.

3. Bronchial asthma somato-psychogenic (BASP). The standard disease progress of patients falling under this category was altered by stress, after which the psychoemotional triggers (exogenous irritants) caused asthma attacks.

Exogenous irritants:

- respiratory infection particularly by viruses;
- chemical irritants;
- drugs (most commonly aspirin);
- occupational asthma such as animal handlers, bakers, workers with wood and vegetable dusts [3].

4. Psychogenic dyspnea (PD). Asthmatic attacks and dyspnea are connected with stressful vital events. The bronchial obstruction and other signs of asthma and organic pathology were ruled out there.

Nowadays we have different methods that allow defining features of patients with different forms of bronchial asthma. For example there is the Lyapunov exponent (λ) - entropic index that characterizes the rate of separation of infinitesimally close trajectories. It is a measure of “irregularity”, smaller values indicate a greater chance that a set of data will be followed by similar data (regularity), and a greater value for the Lyapunov exponent signifies a lesser chance of similar data being repeated (irregularity) (Table 1) [4].

Table 1. Lyapunov exponent

$\lambda < 0$	Negative Lyapunov exponents are characteristics of dissipative or non-conservative systems. Such systems exhibit asymptotic stability; the more negative the exponent, the greater the stability.
$\lambda = 0$	A Lyapunov exponent of zero indicates that the system is in some sort of steady state mode. A physical system with this exponent is conservative. Such systems exhibit Lyapunov stability [5].
$\lambda > 0$	A positive largest Lyapunov exponent indicates chaos.

Research materials

30 people are investigated: 10 healthy (5 men and 5 women), 20 people with bronchial asthma who are divided into 2 groups. The first group includes 12 patients with BAPI (onset and progression of disease associated with psychological stress, psychotraumatic situation), there are 7 men and 5 women. The second group includes BANP, there are 8 people: 4 men and 4 women. While all examinees were sleeping, continuous monitoring of airflow at the nose and mouth was conducted by a cardiorespiratory monitor.

Method

There are two general methods of calculating the Lyapunov exponents: the first is for the data generated by the known system of differential or difference equations, the second is for the data from experimental time series [6].

We have the data of people’s airflow in the form of experimental time series and we do not know its differential equations.

We define the spectrum of Lyapunov exponents in the manner most relevant to spectral calculations. Taking into account a continuous dynamical system in an *n*-dimensional phase space, we monitor the long-term evolution of an infinitesimal n-sphere of initial conditions; the sphere will become an *n*-ellipsoid because the flow has the locally deforming nature. The *i*th one-dimensional Lyapunov exponent is then defined in terms of the length of the ellipsoidal principal axis $p_i(t)$: $\lambda_i = \lim_{t\to\infty} \frac{1}{t} \log_2 \frac{p_i(t)}{p_i(0)}$,

where the λ_i are ordered from largest to smallest.

In this way the Lyapunov exponents are related to the expanding or contracting nature of different directions in phase space. Since the orientation of the ellipsoid changes continuously as it evolves, the directions associated with the given exponent vary in a complicated way through the attractor [7]. The attractor is a set of states - points in the phase space, invariant under the dynamics, towards which neighboring states in the given basin of attraction asymptotically approach in the course of dynamic evolution [8]. One cannot, therefore, speak of a well-defined direction associated with the given exponent.

Notice that the linear extent of the ellipsoid grows as $2^{\lambda_1(t)}$, the area defined by the first two principal axes grows as $2^{(\lambda_1+\lambda_2)t}$, the volume defined by the first three principal axes grows as $2^{(\lambda_1+\lambda_2+\lambda_3)t}$, and so on. This property yields another definition of the spectrum of exponents: the sum of the first *j* exponents is defined by the long term exponential growth rate of a *j*-volume element. This alternate definition will provide the basis of our spectral technique for experimental data.

The sum of the Lyapunov exponents is the time-averaged divergence of the phase space velocity; hence any dissipative dynamical system will have at least one negative exponent, the sum of all of the exponents is negative, and the post-transient motion of trajectories will occur on a zero volume limit set, an attractor [7].

Results

The table 2 shows the Lyapunov exponents according to the sex of healthy people and patients with BAPI and BANP. The results are presented within the accuracy of up to 4 signs.

Table 2. Lyapunov exponents of healthy people and people with BA

Sex	Lyapunov exponents	Healthy people	BANP	BAPI
Women	λ	0,2687	0,2138	0,2477
Men		0,2592	0,2563	0,2468

Let us represent the chart of our Lyapunov exponents to make the data more visible (Fig.1).

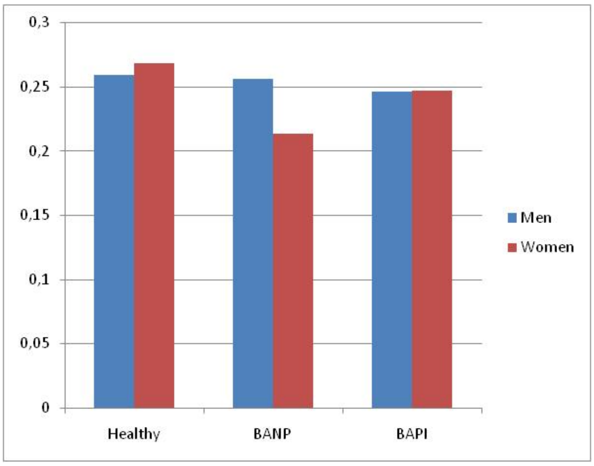

Fig.1. Chart of Lyapunov exponents

Conclusion

Lyapunov's method is applied to study the stability of various differential equations and systems. It effectively identifies differences between healthy people and patients with BA (BAPI and BANP). Looking at the table 2, we can make the following conclusions:

1. Women's Lyapunov exponents are higher than men's, it means that healthy men have more rhythmic breathing.
2. Men with BANP have higher Lyapunov exponents than women's therefore women have more rhythmic breathing.
3. Men and women with BAPI have approximately equal Lyapunov exponents.

Research of nonlinear parameters allows us to reveal different features (in our case features of healthy people and patients with BA). Thus the next step of this research will be to identify nonlinear parameter as correlation dimension to distinguish a "random" system and a system controlled by a small number of parameters, and to assess their complexity.

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