ASSESSMENT OF THE DIAGNOSTIC VALUE OF THE METHOD OF COMPUTER OLFACTOMETRY

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Abstract. Olfactory studies can be a criterion for evaluating rhinosurgical intervention, and olfactory impairment may indicate respiratory impairment. Therefore, the urgent task is to develop an integrated approach to determining respiratory and olfactory disorders. A structural scheme was developed for the method of objective diagnosis of respiratory and olfactory disorders, taking into account the measu, rement of both the aerodynamic parameters of nasal breathing and the calculation of energy characteristics, which are used to determine olfactory sensitivity. The diagnostic significance of the proposed method of analyzing rhinofolipometry data with regard to additional parameters was assessed - it is necessary to take into account the time and power of breathing when the threshold of sensation of the odorivector is at the transition point of the airflow mode to the turbulent quadratic. It has been established that it is advisable to use the energy criteria of nasal breathing, pneumatic power and energy of nasal breathing under the action of the corresponding odor vector for the assessment of respiratory impaired olfactory. To assess the respiratory impairment of olfactory, it is necessary to use the method in which an odor vector is installed in the air path of the rhinomanometer, and the patient is asked to perform breathing maneuvers with a consistent increase in respiration rate while fixing the time at which olfactory sensitivity is achieved and then determining the respiratory energy characteristics. A statistical processing of diagnostic results was carried out, which confirms the adequacy of the model of independent statistical verification and makes it possible to use this method for the functional diagnosis of respiratory-olfactory disorders and testing of respiratory-olfactory sensitivity. The probability index of the error of the second kind is 0.17.

Keywords: odorector, olfakometry, rhinomanometery, nasal breathing

OCENA WARTOŚCI DIAGNOSTYCZNEJ METODY OLFAKTOMETRII KOMPUTEROWEJ

Streszczenie. Badania węchowe mogą być kryterium oceny interwencji chirurgicznej nosa, a zaburzenia węchu mogą wskazywać na zaburzenia oddychania. Dlatego też pilnym zadaniem jest opracowanie zintegrowanego podejścia do określania zaburzeń oddechowych i węchowych. Opracowano schemat strukturalny dla metody obiektywnej diagnostyki zaburzeń oddechowych i węchowych, uwzględniający zarówno pomiar parametrów aerodynamicznych oddychania nosowego, jak i obliczenie charakterystyki energetycznej, które są wykorzystywane do określenia wrażliwości węchowej. Oceniono znaczenie diagnostyczne proponowanej metody analizy danych rhinofolipometrycznych w odniesieniu do dodatkowych parametrów – konieczne jest uwzględnienie czasu i mocy oddychania, gdy próg czucia zapachu znajduje się w punkcie przejściowym przepływu powietrza do trybu turbulentnego. Ustalono, że wskazane jest stosowanie kryteriów energetycznych oddychania nosowego, siły pneumatycznej i energii oddychania nosowego pod wpływem odpowiedniego wektora zapachu do oceny zaburzeń oddechowych. W celu oceny zaburzeń oddychania węchu konieczne jest zastosowanie metody, w której wektor zapachu jest zainstalowany w przewodzie powietrznym rhinomanometru, a pacjent jest proszony o wykonywanie czynności oddechowych ze stałym zwiększeniem częstości oddychania przy jednoczesnym ustaleniu czasu, w którym osiągana jest wrażliwość węchowa, a następnie określenie charakterystyki energetycznej oddechu. Przeprowadzono statystyczną obróbkę wyników diagnostycznych, która potwierdza adekwatność modelu niezależnej weryfikacji statystycznej i umożliwia wykorzystanie tej metody do diagnostyki funkcjonalnej zaburzeń oddechowo-zapachowych i badania wrażliwości oddechowo-zapachowej. Wskaźnik prawdopodobieństwa błędu drugiego rodzaju wynosi 0,17.

Słowa kluczowe: odorivector, olfaktometria, rhinomanometria, oddychanie przez nos

Introduction

Formulation of the problem. The problem of identifying respiratory-olfactory disorders is very complicated in modern otorhinolaryngology, because it requires a comprehensive approach [7, 8]. Objective dysfunction of varying degrees is observed in acute, allergic, vasomotor rhinitis, sinusitis, adenoiditis, nasal polyps, tumors of the nose and paranasal sinuses, infectious granulomas and other diseases. Almost all diseases of the nasal cavity, which occur with obstruction of its lumen, preventing the inflow of air and odors from the olfactory epithelium, suffers from an olfactory function that promotes the launch of various behavioral reactions.To identify smell disturbances, methods based on the subjective evaluation of the subjects (Sniffin' Sticks test, University of Pennsylvania Smell Identification Test, Tastepulvertest Olfactory Display using Pulse Ejection, Hand held smell test and others) are used to a greater extent [9]. The most common and objective instrumental method for the study of respiratory disturbances is the method of quantitative assessment of nasal breathing function - rhinomatometry. This method is based on measuring the difference in pressure between the entrance and exit of the nasal cavity and the passage of air passing through this [24]. It should be taken into account that the disturbance of smell is closely related to the respiratory system. An olfactory study may be a criterion for evaluating rhinoconstrictive intervention, and a violation of the sense of smell may indicate respiratory disturbances. Therefore, the task of developing a comprehensive approach to the identification of respiratory and olfactory disorders is urgent.

1. Analysis of recent research and publications

When conducting anterior active rhinomatometry (AAR), the air flow rate Q is measured through one of the nasal passages and the pressure difference Δp between the atmospheric and in the nasopharynx at the entrance to one of the nasal passages geometrically arranged with a differential sensor, and the breathing is carried out through another nasal passage. The reliability of the diagnosis thus significantly decreases due to the expansion of one nasal course in the tuning of another, and, consequently, the impossibility of the correct algebraic addition of successively measured air flow $Q_{L_{AAR}}$ and $Q_{R_{AAR}}$ through the left and right nasal passages respectively [5].

Active posterior rhinomanometry (APR) involves measuring the total airflow Q when breathing through the nose through both the nasal passages and the pressure drop Δp between atmospheric and in the nasopharynx (the distal end of the measuring tube of the pressure sensor is introduced through the oral cavity) (Fig. 1).

Since the analysis of recent researches and publications has shown that the method of rhinomatometry is the most objective functional method of modern otorhinolaryngology diagnosis, and the method of dynamic active posterior rhinomanometry (APR) is more reliable than the anterior active rhinomatometry, then it is proposed to add a definition to the standard APR method some parameters related to the function of the smell [16, 23].

2. The aim of the study

The aim of the study is to develop a method for analyzing rinolefactometry data for functional diagnosis of respiratory-olfactory disturbances and to evaluate the diagnostic significance of the proposed method.
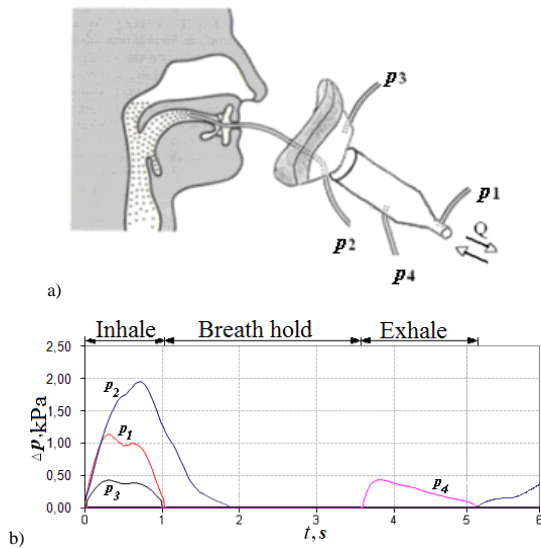

Fig. 1. Location of measuring transducers in the device TNDA-PRH – a, and the corresponding diagram of the respiratory cycle - b [9]

3. Experimental

Thus, a structural scheme of the method for the objective diagnosis of respiratory and olfactory disturbances was developed, taking into account the measurements of both aerodynamic indices of nasal breathing and the calculation of energy characteristics [9, 16, 23], by which the olfactory sensitivity was determined (see Figure 2) [5, 6].
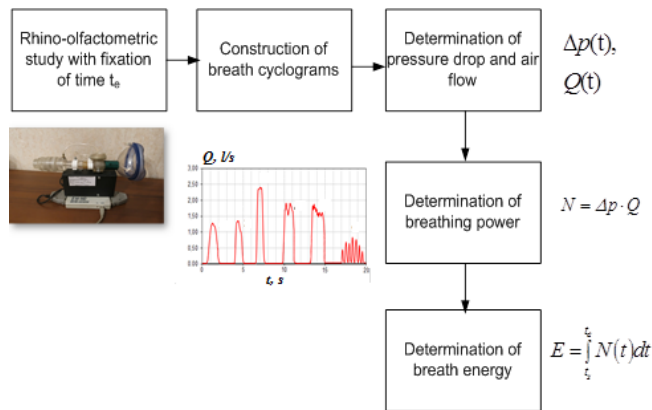

Fig. 2. Structural scheme of the method for the objective diagnosis of respiratory and olfactory disturbances

The computer olfactometry method for determining respiratory-olfactoral disorders in the first stage involves performing the preparation for a dynamic rhinomatometry (rinoflowmetry) procedure, in which measurements of pressure drop Δp on the nasal cavity and air flow rates Q in the nasal breath are measured.

A carrier of a single vector, for example, a hygroscopic cylindrical ring gasket, impregnated with a solution of a specific odorant, is placed in the airway of the rhinomanneter, usually at the inlet of the sensor for measuring the flow of air. As rhinomanometer it is possible to use a rinomanometer such as TNDA-PRH (KHNURE, Ukraine [3]), ATMOS 300 (ATMOS MEDIZINTECHNIK GMBH, Germany) or their analogues [3, 13].

For the study of olfactory sensitivity, three olfactory substances of varying receptor activity are used [9, 13]: a solution of valerianum at a concentration of 0.05% that is caused by the n nerve. olfactorius, acetic acid 0.04%, due to n. trigeminis and ammonia 0.004% due to n. glossopharingeus.

Fig. 3. Study of olfactory sensitivity

Next, the procedure of dynamic rinoflowometry is directly performed with the aid of a rhinomanneter for obtaining respiration cyclones, representing the dependences of the flow of Q (t) and the pressure drop Δp (t) on the nasal cavity from time. Graphic materials presented in Figure 2 are illustrations of the computer rhinomanometer TNDA-PRH with an olfactometric nozzle [6] (certificate of metrological attestation No 05-0102 dated 01.04.2010) [17, 26].

At the same time, the patient performs respiratory maneuvers with an increase in their intensity and the time of the appearance of olfactory sensitivity is recorded automatically. Next, the calculation of the pneumatic power $N(t)$ cyclogram breathing according to the formula (1):

$$N(t) = \Delta p(t) \cdot Q(t). \tag{1}$$

Determination of energy E respiration, which characterizes the calorimetric costs of breathing in the emergence of sensitivity to the odorivector, is carried out by integrating the cyclogram of the pneumatic power of breathing by the formula (2):

$$E = \int_{t_s}^{t_e} N(t) dt \tag{2}$$

where t_s – is the starting time of the study, as a rule, is taken equal to 0; t_e – is the time when the odor vector sensitivity appears.

Integration is performed numerically by the trapezoid method.

Experimental way on the basis of conducted research was developed the classification of the degree of violation of perception of odors (Fig. 3):

E ≤ 2 J – conventionally normal sense of smell;
2 <E ≤ 8 J – average degree of dysosmia;
8 <E ≤ 16 J – severe degree of dysosmia;
E> 16 J – practically complete dysosmia.

The obtained results of the evaluation of the degree of violation of olfactory human function were confirmed by additional laboratory and clinical studies conducted by experts in the otorhinolaryngology department of the Kharkiv Regional Clinical Hospital [23, 24, 29].

4. Results and discussion

We will evaluate the diagnostic significance of the proposed method for analyzing rhinoolfactometry data taking into account additional parameters – it is necessary to take into account the time and respiration power when the threshold of sensation of the odorivector of values Q_s and $\Delta p_s \equiv p_s$ characterizing the transition point of the air flow regime to the turbulent quadratic one. Let's consider a model of linear discrimination for the two states of the object (Θ_0 – conditional norm Θ_1 – the state of breath-olfactory disturbances). The normalized Euclidean distance

between controlled states and with the mutual independence of n characteristics is calculated by the formula (3) [12, 28]

$$\delta = \sqrt{\sum_{i=1}^{n}\left(\frac{m_i^{(0)} - m_i^{(1)}}{\sigma_i}\right)^2} \qquad (3)$$

where $m_i^{(0)}$, $m_i^{(1)}$ – the mean values of the i-th signs of the value of X for the conditions $\Theta \in \Theta_0$ (conditional norm), and $\Theta \in \Theta_1$ (violation of the nasal breathing), respectively, σ_i – mean-square deviations-signs that are determined according to the expression

$$\sigma_i = max(\sigma_i^{(0)}, \sigma_i^{(1)}) \text{ where } \sigma^{(0)^2} \neq \sigma^{(1)^2}$$

where $\sigma_i^{(0)}$, $\sigma_i^{(1)}$ – the mean square deviation is a sign for conditions (conditional norm), and (violation of nasal breathing).

In the normal distribution of values of the measured value, the probability of a second-order error when making decisions about the state of an object is determined through the integral of the Laplace $\Phi(\cdot)$ probability and is estimated by inequality (4) [1, 10]

$$P \leq 1 - \Phi(\delta/2) \qquad (4)$$

where δ is determined by the formula (3).

From formulas (3) and (4) it is obvious that the probability of the error is less, the more the dispersion square of the Euclidean distance is distributed between the vectors of the mean values of the signs [20, 22].

In the proposed method of computer olfakometry take into account the time and power of breath at the threshold of sensation of the odorivector are the following measured physical quantities (with the number of measured parameters n = 5):

X_1 – maximum air flow Q;

X_2 – pressure drop $\Delta p \equiv p$ at maximum air flow;

X_3 – air flow Q_s in the presence of olfactory sensitivity;

X_4 – pressure drop $\Delta p_s \equiv p_s$ at appearance of olfactory sensitivity [29, 30];

X_5 – time t_s of appearance of olfactory sensitivity.

The conditions of the conditional norm and the violation of the nasal breathing are designated, respectively, as Θ_0 and Θ_1. A total of 85 patients were examined, divided into two groups: 40 persons without nasal breathing and 45 persons with nasal breathing disorders. In this case, the maximum values of air flow Q and pressure drop Δp in the nasal cavity (the standard method of forced APR [5, 6, 29]) were determined, as well as during the computer olfactometry, the value of air flow Q_s and pressure drop in the appearance of olfactory sensitivity in the presentation of the corresponding odorector. Then, for each group of patients, statistical indicators were calculated: the mean values and the mean square deviations of the corresponding measured values in the norm and in the respiratory-olfactory disturbances. The results of the calculation of the normalized Euclidean distance for the estimated indicators of the method are shown in Table 1 and displayed on the graph in Figure 4, a. Reducing the probability of a diagnostic solution error by adding the parameters studied to the model of discrimination is shown in Figure 4, b.

It is obvious that the addition of aerodynamic indices Q_s, t_s and Δp_s the point of transition to the turbulent quadratic air flow regime increases the normalized Euclidean distance in comparison with the standard method of forced APR by a value of 0.68 (1.4 times) and accordingly reduces the probability of a diagnostic error by a factor of 2 (from 0.35 to 0.17) [4, 11].

Moreover, it can be noted that the greatest contribution to reducing the probability of error is the air flow, as with standard forced rhinomanometry, and with olfactometry, as well as the time of the appearance of olfactory sensitivity to the odorivector. Pressure differences do not play a significant role in the pattern of discrimination [2, 14].
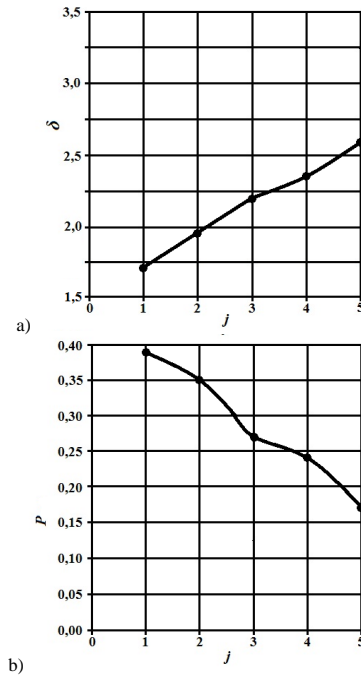

Fig. 4. Dependences of the increase of the normalized Euclidean distance (a) and the reduction of the probability of the decision error (b) as the signs are added to model 1 – for the air flow signal; 2 – for the differential pressure signal; 3 – air flow at the appearance of olfactory sensitivity, 4 – pressure drop in the appearance of olfactory sensitivity, 5 – the time of the appearance of olfactory sensitivity

Table 1. Results of discriminant analysis for the method of data analysis of computer olfaktometry with additional parameters taking into account the time and power of breath at the onset of the threshold of sensation of the odorivector [19, 24, 30]

Parameter		Condition		Normally Euclidean distance δ_Σ	Probability errors P_{δ_Σ}
		Norm	Violations		
		Θ_0	Θ_1		
X_1	Q, l/s	2.64	1.07	1.71	≤ 0.39
	σ_Q	0.92	0.46		
X_2	Δp, kPa	3.75	2.44	1.94	≤ 0.35
	$\sigma_{\Delta p}$, kPa	1.41	0.97		
X_3	Q_s, l/s	0.32	2.40	2.22	≤ 0.27
	σ_{Q_s}	0.11	1.89		
X_4	Δp_s, kPa	1.55	4.61	2.36	≤ 0.24
	$\sigma_{\Delta p_s}$, kPa	0.72	3.86		
X_5	t_s, kPa	1.43	8.52	2.62	≤ 0.17
	σ_{t_s}, kPa	0,35	6,19		

5. Conclusions

It is established that in assessing respiratory disturbances of the sense of smell it is expedient to use energy criteria of nasal breathing, pneumatic power and energy of nasal breath under the action of the corresponding odorivector. To assess respiratory disturbances of the sense of smell, it is necessary to use a method in which the odorivector is installed in the airway of the rhinomatometer and the patient is offered to perform respiratory maneuvers with a sequential increase in the intensity of respiration when fixing the time point at which smell sensitivity is achieved with the subsequent definition of the energy characteristics of respiration [25].

The statistical processing of the diagnostic results is confirmed, which confirms the adequacy of the model of independent statistical verification and makes it possible to use this method for functional diagnostics of respiratory-olfactory disturbances and testing of respiratory-olfactory sensitivity. The probability rate of the 2nd kind of error is 0.17.

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