COMPARATIVE CHARACTERISTICS OF AUTONOMIC IMBALANCE DIAGNOSTIC METHODS IN SCHOOL-AGE CHILDREN

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Summary

Introduction. An imbalance in the autonomic nervous system regulation, known as dysautonomia, is one of the most common clinical syndromes that accompany several diseases. The balance between sympathetic and parasympathetic influences on the body can rapidly change during dynamic processes, especially in cases of infectious and acute diseases, where autonomic regulation plays an active role in shaping the immune response. In children with respiratory diseases, the influence of the vagus nerve (n.vagus) on the frequency and depth of breathing is also important but remains relatively understudied. Assessment of vegetative balance in pediatrics is carried out using various methods depending on the child’s age and condition, with commonly used approaches including questionnaires, calculation of the Kerdo autonomic index, and orthostatic testing.

The aim. To compare the diagnostic capabilities of different methods for assessment of the autonomic nervous system state in school-age children on the model of acute bronchitis.

Materials and methods. The paper presents data from a study that assessed the state of the autonomic nervous system in 52 school-age children (12-16 years old) divided into two groups: 30 children with acute bronchitis in the convalescent period and 22 clinically healthy individuals. Three different methods were used: the A. M. Wayne scale, the Kerdo index, and the orthostatic test.

Results. The survey based on Wayne’s questionnaire did not reveal a significant difference between the groups of healthy children and those affected by bronchitis. Dynamic tests proved to be more suitable for assessing acute pathology, such as Kerdo’s autonomic index and the orthostatic test. The autonomic Kerdo index in children with bronchitis was significantly higher (14.2±2.38 points) than in healthy children (6.4±3.18 points, p<0.05). In children with acute bronchitis, dysautonomia with a predominance of sympathicotonia was recorded, which may be attributed to insufficient vagal innervation and a decrease in parasympathetic influence on the formation of an adequate immune response to the inflammatory process in the respiratory tract.

Conclusions. Determining the autonomic Kerdo index and conducting the orthostatic test is suitable for diagnosing dysautonomia in children with acute respiratory pathology. These tests are dynamic, functionally based, and easy to perform and evaluate.

Key words: children, autonomic dysfunction, Wayne’s questionnaire, Kerdo autonomic index, respiratory diseases

INTRODUCTION

The imbalance in the autonomic nervous system – dysautonomia (DA) – is one of the most common clinical syndromes that accompanies a wide range of diseases and primarily manifests as dysfunction of the cardiovascular, respiratory, endocrine, and nervous systems [1-4]. In clinical practice, there are very few pathological conditions in which autonomic disturbances do not play a significant role in development and course. In some cases, they are an essential factor in the etiopathogenesis and clinical symptomatology, while in others, they arise secondarily in response to damage to various organ systems, creating an autonomic imbalance characterized by a symptom complex of psychomotor, sensory, and vegetative activity disorders related to suprasegmental and segmental disturbances in the autonomous regulation of the functioning of various organs and...
systems [2, 5-7]. Dysautonomia plays a particular role in the pathophysiological changes in psychosomatic disorders, characterized by a syndrome of maladaptation with manifestations such as reduced tolerance to physical exertion, rapid fatigue, decreased work capacity, increased sensitivity to hypoxia, weather sensitivity, and susceptibility to dizziness, and the like. In turn, increased sensitivity to hypoxia can lead to syncopal paroxysms with loss of consciousness or their equivalents [2, 5-10]. These conditions are predominantly vasovagal and orthostatic in terms of their mechanism of occurrence. Dizziness may be preceded by a pre-syncopal state: a feeling of discomfort, nausea, yawning, sweating, weakness in the legs, darkening of vision, noise or ringing in the ears, and so on [11, 12].

The assessment of vegetative balance is conducted using various methods depending on the child’s age, type of pathology, and the child’s condition. A simplified approach to diagnosing DA relies on clinical and anamnestic data, which in domestic medicine is determined through the use of the A. M. Wayne questionnaire [3]. The significant number of items in the questionnaire (11) and its comprehensive nature provide an idea of the overall balance of autonomic innervation in an individual and the systemic nature of DA.

Two common simple methods for assessing vegetative balance are based on the pupillary and orthostatic reflexes. Pupillometry involves measuring the diameter of the pupils using a pupillometer and observing changes in pupil size when exposed to light [13-15]. Since the degree of pupil constriction depends on parasympathetic tone, while dilation depends on sympathetic tone, changes in pupil width reflect the balance of autonomic regulation. This method is particularly useful for examining newborns: in full-term infants, it indicates the state of vegetative balance, and asymmetric reactions may suggest possible traumatic cerebral problems [16]. In preterm infants during the perinatal and postnatal periods, it assesses the degree of development of the autonomic nervous system since there are specific timeframes, a «critical window,» for the atypical formation of the autonomic regulation system [13]. According to Ishikawa M., pupillometry also correlates well with heart rate variability in infants [17].

In preschool and school-age children, the assessment of vegetative balance can be obtained through simple clinical tests: the Kerdo index, calculated based on diastolic blood pressure and heart rate, and the orthostatic test [18]. The orthostatic test (also known as the Waldenfels test) is a functional test based on the effect of changing the tone of the sympathetic division of the autonomic nervous system and, consequently, an increase in heart rate when transitioning from a horizontal (clinostatic) to a vertical (orthostatic) position [19]. This test is also widely used in adults, especially in sports medicine and geriatrics. It is easy to administer, as it only requires counting the pulse rate during the position change [20, 21]. The most technically complex procedure is ECG monitoring and the calculation of heart rate variability parameters. However, it is currently considered the «gold standard» for assessing the balance of the autonomic nervous system and diagnosing dysautonomia.

The balance between sympathetic and parasympathetic influences on the body rapidly changes in dynamic processes, especially in cases of infectious diseases and acute illnesses, where autonomic regulation plays an active role in shaping the immune response and controlling its course [22]. Thayer J. F. emphasizes the special role of afferent and efferent parasympathetic regulation, and in the case of respiratory diseases, the significant influence of the vagus nerve (n.vagus) on the frequency and depth of breathing. Guyenet PG shares a similar viewpoint and points out the potential parasympathetic control of the immune response through efferent neural pathways [23]. Several pathological conditions related to dysautonomia are also observed in respiratory pathology in the form of breathing disorders (vagotonic bronchial asthma, paroxysmal psychogenic coughing attacks, breathlessness, psychogenic dyspnea attacks). In contemporary circumstances, there is increased attention to autonomic innervation disorders in the functioning of the respiratory system, particularly due to the COVID-19 pandemic and the emergence of long COVID in certain cases [24, 25]. The concept of dysautonomia’s presence in respiratory diseases necessitates consideration of changes in this sphere, their diagnosis, and appropriate correction of treatment measures.

THE AIM OF THE ARTICLE

To compare the diagnostic capabilities of various methods for assessing the state of the autonomic nervous system in school-age children with respiratory diseases.

MATERIALS AND METHODS

The study was based on the assessment of the autonomic nervous system in 52 school-age children (12-16 years old) divided into two groups: 30 children with acute bronchitis in the convalescent period and 22 clinically healthy individuals. Three different methods were used: the A. M. Wayne scale, the Kerdo index, and the orthostatic test.

The A. M. Wayne questionnaire (short version) consisted of 11 items with scores ranging from 0 to 7, depending on the nature and presence or absence of symptoms. The total score of Wayne’s index below 15 points indicates the absence of dysautonomia, while a score higher than 15 points suggests a certain level of autonomic dysfunction. The Kerdo vegetative index was calculated using the formula: \( VI = (1 - DBP / HR) * 100 \), where DBP is the diastolic blood pressure level, and HR is the heart rate per minute. In a state of complete autonomic balance in the
cardiovascular system, the VI is approximately equal to 0 (ranging from –4 to +4). Higher positive values of the index indicate sympathetic dominance in vascular tone regulation, while negative values indicate increased parasympathetic tone. The orthostatic test was performed by calculating the heart rate while lying down for 15 minutes and immediately after the subject transitioned from a horizontal to a vertical position (pulse rate counted for 15 seconds multiplied by 4). Then, the heart rate was measured again after 3 minutes, a period when the heart rate stabilizes. A normal response to the test is an increase in heart rate by 10-16 beats per minute immediately after the transition, followed by stabilization with a pulse rate that remains 6-10 beats per minute faster than in the horizontal position. A stronger reaction indicates heightened reactivity of the sympathetic part of the autonomic nervous system, while a weaker reaction is observed in cases of reduced reactivity of the sympathetic part and increased parasympathetic tone. The obtained results were statistically analyzed using the Statistica 6.0 program (StatSoft) with parametric and non-parametric methods. The level of significance was set at p < 0.05 for determining the probability of differences, following the commonly accepted standard in medical and biological research.

RESULTS AND DISCUSSION

The groups of children included in the study did not differ significantly in terms of age and gender composition. They also had no history of chronic illnesses or autonomic nervous system disorders. Children with acute bronchitis had a moderately severe course of the disease at the time of hospitalization, with an average hospital stay of 7.4±0.53 days, followed by continued outpatient treatment. The examinations were conducted 1-2 days before discharge from the hospital. The Wayne questionnaire did not reveal a significant difference between the groups. Children with bronchitis had a score of 15.6±0.98 points, while healthy individuals scored 15.0±1.23 points (p>0.05). However, in both cases, the scores were within the borderline diagnostic range.

Another indicator, the Kerdo vegetative index, in children with bronchitis was significantly higher (14.2±2.38 points) than in the control group of children (6.4±3.18 points, p<0.05). In healthy children, there was a slight dominance of sympathetic nervous system tone according to this index, whereas in convalescents, it was significantly higher, indicating the presence of some imbalance in the autonomic nervous system regulation. A structural analysis of the VI indicator shows its heterogeneity in the group of children with acute bronchitis, with a higher number of individuals with high scores (Figure 1). This skewness in the sample is confirmed by its indicator, which is at the level of −0.83±0.42. The increase in the number of children with high scores in the group with respiratory diseases (76 %) demonstrates active participation of the sympathetic nervous system, which can be interpreted as a component of dysautonomia in the pathogenesis of the disease.

![Histogram of the VI (Vegetative Index) indicator in the examined children.](image)

Table 1

<table>
<thead>
<tr>
<th>Group</th>
<th>The heart rate per minute (beats per minute)</th>
<th>Difference from initial heart rate</th>
<th>Stabilisation period, 3 min.</th>
<th>Difference with the initial heart rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before the test, horizontal position</td>
<td>Vertical position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children with acute bronchitis</td>
<td>74.8±1.2</td>
<td>103.5±2.2*</td>
<td>28.7</td>
<td>96.5±2.2*</td>
</tr>
<tr>
<td>Clinically healthy children</td>
<td>75.8±2.3</td>
<td>93.4±2.8</td>
<td>17.6</td>
<td>84.5±2.2</td>
</tr>
<tr>
<td>Note: – significant difference between groups, p&lt;0.05</td>
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The orthostatic test, despite its simplicity in execution, also demonstrated its suitability for assessing the balance of the autonomic nervous system. The response to the transition from the clinostatic position to the orthostatic position in children with acute bronchitis indicates the predominance of sympathetic tone (Table 1) and a slower process of heart rate stabilization, which is also characteristic of a stronger sympathetic influence. In the comparison group of children, the test results are practically within the balance zone with a slight increase in sympathetic tone. During the stabilization period, the heart rate returns to the range typical for eutonia.

In our study, most children with bronchitis exhibited dysautonomia with a predominance of sympathicotonia. However, since dysautonomia represents a balance between the two branches of the autonomic nervous system, this result may be associated with insufficient vagal innervation and a decrease in its influence on the production of an adequate immune defense response to the inflammatory process in the respiratory tract. American researchers (Thayer J. F. et al., 2011) emphasize the critical role of the parasympathetic system in the process of immunomodulation during acute conditions [26]. Thanks to the vagus nerve, a chain is activated that involves the identification of the pathogenic factor through afferent fibers and receptors to interleukin IL-1, stimulating the production of pro-inflammatory cytokines. Additionally, parasympathetic influences have been found to promote vasodilation and increased blood flow to immune structures. In any case, such responses lead to a shift in the balance of the autonomic nervous system and contribute to the development of dysautonomia.

CONCLUSIONS

1. The assessment of autonomic nervous system balance using the Wayne questionnaire is ineffective in cases of acute pathology because the test itself relies on generalized anamnestic reactions over an extended period.

2. Determining the Kerdo vegetative index and conducting the orthostatic test are suitable for diagnosing dysautonomia in children with acute respiratory pathology. These tests are dynamic, based on functional parameters, easy to perform, and evaluate the results.

PROSPECTS FOR FURTHER RESEARCH

Prospective directions for further research in this area include selecting pathological conditions for the clinical application of dysautonomia diagnostic methods in children with respiratory diseases and searching for drugs suitable for correcting disorders in this field.

COMPLIANCE WITH ETHICAL REQUIREMENTS

The study was conducted in accordance with the principles of the World Medical Association’s Declaration of Helsinki «Ethical Principles for Medical Research Involving Human Subjects». Informed consent to participate was obtained from all those included in the study, which emphasises the absence of invasive interventions. The study protocol was discussed and approved at a meeting of the Biomedical Ethics Committee of Bukovinian State Medical University.

FUNDING AND CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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Резюме

ПОРІВНЯЛЬНА ХАРАКТЕРИСТИКА МЕТОДІВ ДІАГНОСТИКИ ВЕГЕТАТИВНОГО ДИСБАЛАНСУ У ДІТЕЙ ШКІЛЬНОГО ВІКУ
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Вступ. Дисбаланс у системі автономної нервової регуляції – дизавтономія, є одним з найбільш частих клінічних синдромів, які супроводжують цілу низку захворювань. Співвідношення симпатико-парасимпатичних впливів на організм швидко міняються в динамічних процесах, особливо у випадках інфекційних захворювань та гострих хвороб, при яких автономна регуляція приймає активну участь у формуванні імунної відповіді. У дітей з респіраторними захворюваннями важливим і мало вивченим також є вплив n.vagus на частоту та глибину дихання. Оцінка вегетативного балансу у педіатрії проводиться різними методами в залежності від віку, стану дитини і найчастіше визначається за допомогою анкетування, розрахунку вегетативного індексу Кердо та ортостатичної проби.

Мета. Порівняти діагностичні можливості різних методик оцінки стану вегетативної нервової системи у дітей шкільного віку на моделі гострого бронхіту.

Матеріали та методи. Дослідження побудовано на оцінці стану вегетативної нервової системи у 52 дітей шкільного віку (12-16 років) у двох групах (30 дітей з гострим бронхітом у період реконвалесценції та 22 клінічно здорових особи). Застосовувалися три різних методики: шкала А. М. Вейна, індекс Кердо, ортостатична проба.

Результати. Опитування за анкетою Вейна не виявило суттєвої різниці між групами здорових та хворих на бронхіт дітей. Більш придатними при гострій патології виявилися динамічні проби: вегетативний індекс Кердо, ортостатична проба. Вегетативний індекс Кердо у дітей з бронхітом був вірогідно вишим (14,2±2,38 балів) ніж у здорових дітей (6,4±3,18 балів, р<0,05). У дітей з гострим бронхітом реєструвалася ДА з перевагою симпатикотонії, що можливо пов’язано із недостатньою вагальною іннервацією та зниження парасимпатичного впливу на формування достатньої імунної відповіді на запальний процес у дихальних шляхах.

Висновки. Визначення вегетативного індексу Кердо та проведення ортостатичної проби придатні для діагностики дизавтономії у дітей з гострою респіраторною патологією. Ці проби є динамічними, базуються на функціональних показниках, прості у виконанні та оцінці результатів.

Ключові слова: діти, вегетативна дисфункція, опитувальник Вейна, вегетативний індекс Кердо, респіраторні захворювання