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THE ROLE OF INNOVATIVE TECHNOLOGIES IN THE REHABILITATION OF CHILDREN WITH RESPIRATORY DISEASES: PROSPECTS AND ADVANTAGES

Introduction. Modern innovative technologies play a key role in the rehabilitation of children with diseases of the respiratory system, significantly improving the quality of medical care and treatment results. Technological progress in medicine opens up new opportunities for early diagnosis, monitoring and rehabilitation, providing more accurate and individualized treatment of patients.

The effectiveness of lung disease therapy depends not only on the correct choice of the drug, but also on the method of its delivery to the patient's body. Inhalation route of administration of medical aerosols It is the most effective way of delivering medicines for lung diseases: the drug is sent directly to the place of its action – into the respiratory tract of the patient [1]. The key to successful inhalation therapy is not only the properties of the drug (its chemical structure), but also factors such as choosing the optimal delivery system and teaching the patient inhalation techniques [2]. The ideal delivery device should ensure the deposit of a large fraction of the drug in the lungs, be fairly easy to use, reliable, available for use at any age and in severe stages of the disease. The main types of delivery systems include: metered-dose aerosol inhalers (DAI), metered-dose powder inhalers (DPI), liquid inhalers (soft mist inhalers) and nebulizers [3].

New generation Portable inhalers.

1.Improving efficiency: Portable inhalers provide more efficient delivery of medicines to the respiratory tract, allowing you to adjust the dosage and treatment regimen to the patient's condition.

2. Ease of use: Portable inhalers are becoming an indispensable tool in the treatment of children, as their use is possible at home, which reduces the frequency of hospitalizations and improves the quality of life.

Indications for the use of nebulizers. There are few absolute indications for the use of nebulizers. They should be used when [4]:

1) the medicinal substance cannot be delivered to the respiratory tract using other inhalers, because there are quite a lot of medicines for which portable inhalers (DAI and DPI) have not been created: antibiotics, mucolytics, surfactant preparations, prostanoids, etc.;

2) delivery of the drug to the alveoli is necessary (for example, surfactant preparations in acute respiratory distress syndrome);

3) the severity of the patient's condition or his physical condition the condition does not allow the correct use of portable inhalers. This indication is the most important and significant when choosing an inhalation technique. Despite the well–known advantages of metered-dose inhalers (DI) - small size, lower cost, speed of use, their use requires clear coordination between the patient's inhalation and the release of the drug, as well as forced maneuver. The elderly age of the patient can often be an obstacle to the proper use of all types of inhalation equipment, except the nebulizer. The nebulizer is also the only possible means of delivering aerosol drugs in children under 3 years of age.

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Objective criteria requiring the appointment of inhalations using nebulizers include: reduction of inspiratory vital capacity of less than 10.5 ml/kg of weight (for example, < 730 ml in a patient weighing 70 kg); inspiratory flow of the patient is less than 30 l/min; inability to hold breath for more than 4 seconds, in addition, the use of nebulizers is indicated in patients with motor disorders, impaired consciousness [7].

All other indications are relative (i.e. in these situations, the nebulizer can be replaced with other inhalation systems):

1) the need to use a large dose of the drug. The dosage of medications may depend on the functional severity of the disease. The maximum response to inhaled medications in severe bronchial obstruction can beachieved only with the use of high doses of drugs [8]. The reasons for such a physiological response in severe bronchial obstruction may be the presence of anatomical obstacles (secret, spasm, mucosal edema and other disorders) for drug access to receptors and, possibly, the need for a larger proportion of available receptors to achieve maximum response;

2) the preference of the patient, which is expressed in the fact that many patients during an exacerbation of the disease prefer to use therapy and techniques other than the one they use in a familiar, home environment;

3) Practical convenience. Despite the fact that the effectiveness of inhalation technology when using. The operation with a spacer and a nebulizer is approximately the same in many situations, the use of nebulizers is a simpler method of therapy, does not require teaching the patient breathing maneuvers and monitoring the inhalation technique by a doctor. In the case of using a nebulizer, the doctor can be sure that the patient receives the exact dose of the drug.

It should also be recalled about the other advantages of the nebulizer in comparison with other means of delivery – if necessary, oxygen can be used during inhalation.

The delivery of the drug to the respiratory tract depends on.

There are many factors, the most important of which is the particle size of the medicinal aerosol. Conditionally, the distribution of aerosol particles in the respiratory tract, depending on their size, can be represented as follows (Fig. 1):

• more than 10 microns − deposition in the oropharynx;

• 5-10 microns − deposition in the oropharynx, larynx and trachea;

• 2-5 microns − deposition in the lower respiratory tract;

• 0.5–2 microns − deposition in the alveoli;

• less than 0.5 microns − they are not deposited in the lungs [9].

The effectiveness of aerosol production, its properties and delivery to the respiratory tract depends on the type of nebulizer, its design features, the combination of the compressor – nebulizer system, etc. However, traditional nebulizers are not without drawbacks, such as a long inhalation time, a relatively low pulmonary deposit of drugs, the possibility of contamination of equipment with improper maintenance.

The principle of operation of nebulizers.

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For many years, depending on the type of energy that turns a liquid into an aerosol, 2 have been isolated. The main types of nebulizers: 1) jet – using a jet of gas (air or oxygen); 2) ultrasonic (ultrasonic) – using the oscillation energy of a piezocrystal [10, 11]. Relatively recently (about 3 years ago), a new, third type of nebulizers appeared – membrane ones, which, thanks to a new principle of operation, make it possible to overcome many disadvantages associated with the use of traditional nebulizers.

Jet nebulizers. The principle of operation of the jet nebulizer is based on the Bernoulli effect [12]. Air or oxygen (working gas) enters the nebulizer chamber through a narrow opening (which is called Venturi). At the outlet of this hole, the pressure drops, the gas velocity increases significantly, which leads to the suction of low-pressure liquid into this area through narrow channels from the chamber reservoir [4, 12]. When a liquid meets an air stream, under the action of a gas jet, it breaks into small particles, the sizes of which vary from 15 to 500 μm – this is the so-called "primary" aerosol. In the future, these particles collide with a "flap", resulting in the formation of a "secondary" aerosol – ultrafine particles with a size of 0.5 up to 10 μm (about 0.5% of the "primary" aerosol), which is further inhaled, and a large proportion of the particles of the "primary" aerosol (about 99.5%) is deposited on the inner walls of the nebulizer chamber and is again involved in the aerosol formation process.

Ultrasonic nebulizers. Ultrasonic nebulizers for aerosol production use the energy of high-frequency vibrations of a piezocrystal. A high frequency signal (1-4 MHz) deforms the crystal, and vibration from it is transmitted to the surface of the drug solution, where "standing" waves are formed [13]. With sufficient frequency The ultrasonic signal at the crosshair of these waves is the formation of a "microfontane" (geyser), i.e. the formation and release of an aerosol. The particle size is inversely proportional to the acoustic frequency of the signal of 2/3 degree. Particles of a larger diameter are released at the top of the geyser, and smaller ones at its base [14]. As in the jet nebulizer, aerosol particles collide with the "flap", larger ones return back to the solution, and smaller ones are inhaled (Fig. 3). Aerosol production in the ultrasonic nebulizer is almost silent and faster compared to jet [12]. However, their disadvantages are the inefficiency of aerosol production from suspensions and viscous solutions; as a rule, a larger residual volume; an increase in the temperature of the drug solution during nebulization and the possibility of destruction of the structure of the drug [15].

Membrane nebulizers. The new generation of nebulizers has a fundamentally new device of operation: they use a vibrating membrane or plate with multiple microscopic holes (a sieve) through which a liquid medicinal substance is passed, which leads to the generation of an aerosol [16]. The new generation of nebulizers has several names: membrane, electronic, Vibrating Mesh Nebulizers (VMN) or mesh nebulizers.

In these devices, the particles of the "primary" aerosol correspond to the size of the respirable particles (slightly larger than the diameter of the holes), so the use of a flap is not required. This type of technology involves the use of small filling volumes and the achievement of higher values of pulmonary deposit compared to conventional jet or ultrasonic nebulizers. There are 2 types of membrane nebulizers: those using "passive" membrane vibration and "active" [17].

In nebulizers using "active" membrane vibration, the membrane itself is subjected to vibration from a piezoelectric crystal. The pores in the membrane have a conical shape, while the widest part of the pores is in contact with the drug [18]. In nebulizers of this type, deformation of the membrane towards the liquid medicinal substance leads to the "suction" of the liquid into the pores of the membrane. Deformation of the membrane in the other direction leads to the release of aerosol particles towards

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the respiratory tract of the patient. The principle of "active" membrane vibration is used in AeroNeb Pro nebulizers and AeroNeb Go (Aerogen) and eFlow (Pari).

In devices based on "passive" the vibration of the membrane, the vibrations of the transducer (horn) affect the liquid medicinal substance and push it through a sieve, which fluctuates with the frequency of the horn [17]. Unlike traditional jet or unibulizers, the aerosol, which is formed when a liquid medicinal substance passes through a membrane sieve, does not undergo reverse recycling and can be immediately delivered to the respiratory tract of the patient. The principle of "passive" membrane vibration is used in the OMRON Micro AIR U22 nebulizer (OMRON Healthcare, Japan) – the smallest nebulizer in the world [19].

Unlike traditional ultrasonic nebulizers, in membrane nebulizers, the oscillation energy of the piezocrystal is directed not at a solution or suspension, but at a vibrating element, therefore, there is no warming and destruction of the structure of the medicinal substance.

Due to this, membrane nebulizers can be used for the inhalation of proteins, peptides, insulin and antibiotics [16]. In an in vitro study by Y. Yoshiyama et al. it was shown that the membrane nebulizer OMRON U22 is capable of efficiently producing aerosol from budesonide suspension, while aerosol yield it is 70% of the dose of the drug [20].

Potential disadvantages of membrane nebulizers include the possibility of clogging miniature holes with aerosol particles, especially when using suspensions [16]. The risk of clogging the holes depends on the frequency and conditions of inhaler treatment. Due to the higher efficiency of membrane nebulizers, when using them, a reduction in standard doses and the volume of filling of medicines is required.

New technical solutions nebulizer therapy. Among the new technical solutions in the field of nebulizer technologies, it is possible to note the further development of traditional jet nebulizers. Compressors have been created that, due to their small size, bring nebulizers closer to portable delivery devices (and at the same time are not inferior to more massive "colleagues" in terms of technical characteristics). New solutions have appeared in the class of adaptive delivery devices − dosimetric nebulizers, the fundamental difference of which is daptation of aerosol production and release with the patient's respiratory pattern. The device automatically analyzes the inspiratory time and inspiratory flow of the patient, and then, based on this analysis, the device ensures the production and release of aerosol during the first 50% of the subsequent inhalation. Inhalation continues until the output of the precisely set dose of the drug is reached, after which the device beeps and stops inhalation. An example of this type of nebulizer is I-nebTM (Philips Respironics, US) and AKITA Inhalation System (Aktivaero GmbH, Germany).

And finally, the improvement of classic models of jet nebulizers continues. It should be remembered that jet nebulizer systems (i.e. nebulizer compressor) from different manufacturers are not absolutely identical in their effectiveness, and this must be taken into account when choosing a delivery system for hospital or home inhalation therapy. In practice, comparing the effectiveness of different nebulizer systems is a very difficult clinical task. For this A clinical study is required to evaluate the effectiveness of bronchodilators in patients with obstructive pulmonary diseases. Conducting this type of research is much more time-consuming and responsible compared to bench and laboratory studies, for this reason, very few such works are performed today. Therefore, the results of a recently presented study comparing the effectiveness of two different systems of jet nebulizers deserve attention.

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T. Sukumaran et al. A randomized controlled trial was conducted that included 60 patients with bronchial asthma (children aged 7 to 13 years with a peak (maximum) exhalation rate (PSV) of less than 70% of the required values) [22]. Patients were randomly divided into 2 groups: the first group of patients (n=30) received therapy with salbutamol solution (0.15 mg/kg body weight dissolved in 2 ml of saline solution) using nebulizer NE-C900 (OMRON Healthcare), and the second group received the same therapy using the Redimist nebulizer (RE). To obtain acceptable PSV readings, at least three maneuvers were performed to assess this indicator before inhalation with salbutamol and after 15 and 30 minutes. after inhalation.

Conclusion: Innovative technologies open up new horizons for improving the health and quality of life of children with diseases of the respiratory system. The integration of portable inhalers, monitoring systems, telemedicine and gaming techniques makes the treatment process more flexible, personalized and accessible. This comprehensive approach makes it possible to increase the effectiveness of rehabilitation, reduce the frequency of hospitalizations and improve the prognosis for patients.

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