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Speleotherapy, halotherapy, haloaerosoltherapy: definitions, mechanisms of influence, perspectives of usage (part II)

Key words: *speleotherapy, halotherapy, haloaerosoltherapy, haloinhalation therapy.*

The first part of the review discussed the problem of the place of speleotherapy in the system of pulmonary rehabilitation. It clearly stated that speleotherapy is the use of karst caves and mine workings with curative purposes. That is, the obligatory component of such treatment is the stay of patients in underground conditions for a certain time, while any therapeutic or prophylactic measures carried out on the surface of the earth have no speleotherapeutic effects and can not be referred to speleotherapy. This statement is based on a detailed examination of the mechanisms of curative effect of speleotherapy, as well as the analysis of scientific literature on this subject published by foreign and Ukrainian researchers. Everything seems absolutely clear: everything that is not related to the stay of patients in underground conditions is not speleotherapy; however, some unconscientious authors try to use the authority of speleotherapy which indicates a lack of professionalism of such publications and eventually leads to the discreditation of this treatment method. Other terms, such as halotherapy, haloinhalation therapy, artificial microclimatotherapy, haloaerosol therapy, etc. are still more ambiguous due to objective reasons.

The aim of the study is to carry out an analysis of current developments of treatment methods using rock salt or sodium chloride solutions in conditions on the surface on the earth and to evaluate their effectiveness, as well as to determine the most correct terms for the definition of these methods.

From the first days of the work of speleotherapeutic departments, it was clear that their capabilities were somewhat limited: firstly, due to the existing technical barriers, and secondly, due to contraindications for certain

categories of patients to descent underground. Therefore, the question arose about the development of therapeutic technologies in conditions on the surface, which could at least simulate certain parameters of underground conditions, and thus expand the possibilities for pulmonary rehabilitation. The first scientific developments in this field were conducted in the former Soviet Union, at the Uzhhorod Branch of the Odessa Scientific-Research Institute of Health Resort Medicine (UzhBOSRIH, today Government Institution «The Scientific-practical Medical Centre «Rehabilitation» Health Ministry of Ukraine») under the leadership of Prof. Torokhtin M.D. with the assistance of biologist Zheltvay V.V., Ph D. These studies were based on the idea of creating of rock salt aerosol media – haloaerosol (halite is a mineral of sodium chloride) with the help of certain devices (halogenerators) [12, 15].

The principle of the halogenerator's work is to grind the rock salt to a certain size and then pumping the air into the room where the procedure is carried out. The preparation of the haloaerosol medium requires a certain time until the haloaerosol concentration reaches the necessary level. The first experimental device for the creation of dry rock salt aerosol medium was developed in 1978 (the USSR Certificate of authorship No. 1140296, dated July 5, 1982). [20]. The question about the proper term for this method of treatment arose immediately. In the early period of the research, the terms «artificial speleotherapy», «chambers of artificial microclimate» and «microclimate therapy» [17, 18] were often used. However, they can not be considered correct. Firstly, speleotherapy means staying in underground conditions, in which there are a number of factors, and not just rock salt aerosol. Secondly, this method as it is used today, is not a complete reproduction of a certain microclimate with all relevant

parameters, but only rock salt aerosol presence, which primarily provides local influence on the tracheo-bronchial mucosa. At the same time, the parameters of these aerosols can differ significantly from those in salt mines (including those in Solotvyno). Thus, this therapy only applies the very idea of using rock salt aerosol for therapeutic purposes.

It should be noted that during the first attempts to create an aerosol medium of sodium chloride in UzhBOSRIH, the wet aerosol technology was used. To obtain this aerosol medium, a 20% aqueous solution of sodium chloride was sprayed with a «Comfort» type device [19]. However, it was discovered during the research that, firstly, wet aerosols are rather unstable and this complicates the achievement and maintenance of certain parameters of such an aerosol medium, and secondly, about 20–25% of patients had pronounced balneoreactions in the form of cough attacks and bronchospasm. Today, the ability of sodium chloride hypertonic solutions to cause bronchospasm is universally accepted and even used with a diagnostic purpose to evaluate bronchial hyperreactivity [5, 9, 24, 40]. Along with this, individual inhalations of sodium chloride hypertonic solutions have not completely lost their value, and certain types of them are used, in particular, in the treatment of cystic fibrosis [36, 40, 43].

In addition, there are data on the use of wet haloaerosols in Poland, created with the device called «Minita», but the characteristics of this aerosol and the indications for its use are not specified [26].

A special device for the dry aerosol medium creation called «aerosol generating device» (AGD) was developed by UzhBOSRIH for serial production, an instruction on the method treatment with the use of this device for patients with bronchial asthma was also developed. This allowed wide introducing this method of treatment in more than 100 health care institutions in Ukraine [18]. However, these devices have already exhausted their resources and the work of the departments with therapeutic use of dry rock salt aerosol media practically stopped everywhere.

The researchers of Perm State Technical University and Perm State Medical Academy in Russia used other approach – they did not use halogenerators. They covered the walls with sylvinite rock blocks of certain size (sylvinite is a rock that contains potassium salts and sodium chloride) and used special ventilation systems. Air from the external environment is passed through variable volumes of crushed rock salt (sylvite) with the use of a ventilator and air conditioner [2]. The researchers argue that thus the air purification and aerosol enrichment by the particles of sylvinite rock and negative air ions are carried out. However, with such technology, the concentration of the dispersed phase of aerosol reaches no more than 0,07 mg/m³, while in the underground department of the salt mines in Berezniki (Perm region of Russia) it is 3,7–5,3 mg/m³ [2]. That is, the haloaerosol concentration is 28,6 times smaller than the generally accepted minimal limit (2 mg/m³) [37, 44, 47], which provides therapeutic effect [12, 34]. This questions the significant therapeutic effect of the artificially created aerosol by the method described above. This technology was first implemented in 1989 and was named «sylvinite

speleoclimatic chamber» [16]. This term is incorrect due to the absence of underground conditions and complete reproduction of the microclimate characteristics of the underground conditions in the salt mines of Berezniki.

A significant contribution to the development of devices for the production of rock salt aerosol media was made by P.P. Gorbenko, who worked as the Chief Doctor of the Republican Allergological Hospital (now the Ukrainian Allergological Hospital in Solotvyno) and later made a successful career at the All-Union Center for the Prevention of Respiratory System Diseases «Aerosol» (Saint-Petersburg). In 1985 he developed (co-authored) a «halochamber», a therapeutic and climatic complex (the USSR Certificate of authorship No. 1225569, dated November 13, 1984) [3]. The original version of this complex did not provide for the presence of a halogenerator, and haloaerosol was created at the expense of mass exchange of the air with the walls that were covered with salt blocks, just like in the «sylvinite speleoclimatic chamber». The data on the concentration of such haloaerosol are not available in literature. Only later works (1991) contain a detailed description of the methodology and indicate the presence of the halogenerator and audiovisual influence [4]. However, there is no information on the concentration of haloaerosol and its dispersion. In subsequent publications it is indicated that the concentration of haloaerosol can reach 10 mg/m³, and the salt coating of the walls does not provide the creation of haloaerosol in therapeutic concentrations [23].

In general, the idea of this technology (the creation of dry rock salt aerosol media with certain parameters) corresponded to that developed in UzhBOSRIH, although the procedure itself was somewhat improved and modified. P.P. Gorbenko also proposed the term «halotherapy» for treatment methods which use aerosols of rock salt [4]. This term has become widely used, including in the countries of Western Europe and America [38, 39]. Over time, however, the term «halotherapy» was used to define different methods (means) in which there is halite or sodium chloride solution, but there is no evidence of the presence of haloaerosol as a curative factor. Thus, the use of these methods with therapeutic and prophylactic purposes is highly disputable.

An incorrect explanation of the term «halotherapy» is given even in a comment to the Appendix to the Order of the Ministry of Health of Ukraine No. 555, June 27, 2013 «Chronic Obstructive Pulmonary Disease. Adapted Clinical Instruction Based on Evidence», which states that halotherapy is a method treatment with the presence of artificially created microclimate of salt caves [6]. Thus, it is unclear exactly what microclimate parameters are of importance, how they are created and which «salt caves» in fact, are meant.

Today, under halotherapy, several methods are meant that use halite or sodium chloride (mono influence or in combination with other factors) in the form of a solution or rock salt with therapeutic, recreational purpose, or those one with unclear mechanisms of influence and sphere of application (Fig. 1).

In the broad sense of the term, «halotherapy» refers to the use of wet and dry aerosols with a certain content of sodium chloride as from a natural source, and received with the help of special devices [26]. Natural wet haloaerosols primarily include aerosols in the coastal zone of the seas, but the term «halotherapy» is not applied to them [26]. In addition, the formation of such natural aerosols is organically associated with certain characteristics of the microclimate, which namely corresponds to the term «microclimate therapy». Their influence on the human body is complex and serves as the basis for spa treatment.

Microclimate therapy can also refer to aerosols produced by cooling towers. Such technologies are applied in Poland and Germany (Fig. 2) [26, 29, 33]. Cooling towers are special structures in the form of original towers, which are made using natural materials, such as branches of black-thorn. Earlier they were used to increase the concentration of brine washed out of salt layers, for obtaining salt. Nowadays, they are used as large inhalers in the open air. Brine is lifted to the top of the tower and then falls down through the cooling tower. This is accompanied by the formation of wet haloaerosol around the tower, which, in combination with other parameters of the climate of the area, contributes to the formation of a certain microclimate used in spa treatment and recreation [28, 33]. The concentration of such aerosol can range from $1,6 \text{ mg/m}^3$ to 67 mg/m^3 , but this value is rather unstable and depends on both the distance from the cooling tower and the weather conditions, especially winds. The chemical composition of the brine determines the peculiarities of its influence on the organism [26, 28, 29, 33].

Along with this, there is a study that links haloaerosol produced in cooling towers with outbreaks of legionellosis [46]. The authors argue that there are data that allow associating these outbreaks with inadequate maintenance of cooling towers and their legionella contamination. The work focuses on the need for appropriate maintenance of these structures.

The most correct term for dry rock salt aerosol media with certain parameters of concentration (not less than $2\text{--}3 \text{ mg/m}^3$) and dispersion, which are obtained by means of special devices (halogenerators) and are used primarily for therapeutic purposes, is «haloaerosoltherapy». This term clearly indicates the main curative factor – rock salt aerosol. Notably, when using the term «halotherapy» with respect to dry rock salt aerosol media, in recent publications it is often specified that under halotherapy haloaerosoltherapy is meant [21].

The advantages of dry haloaerosols using are based on certain objective factors. The researchers of the Institute of Geology and Geophysics of the Siberian Branch of the Academy of Sciences of the USSR (head of the project Prof. Yu.P. Kazansky) while studying the geological aspects of speleotherapy in a salt mine of Solotvyno proved that dry haloaerosol has active properties that increase its effect due to certain physical properties of the dispersed phase and the crystalline structure of the dry aerosol particles [8]. In addition, some researchers argue that dry haloaerosol has higher surface energy and a high negative



Fig. 2. Cooling Tower in Czechochynek (Poland)

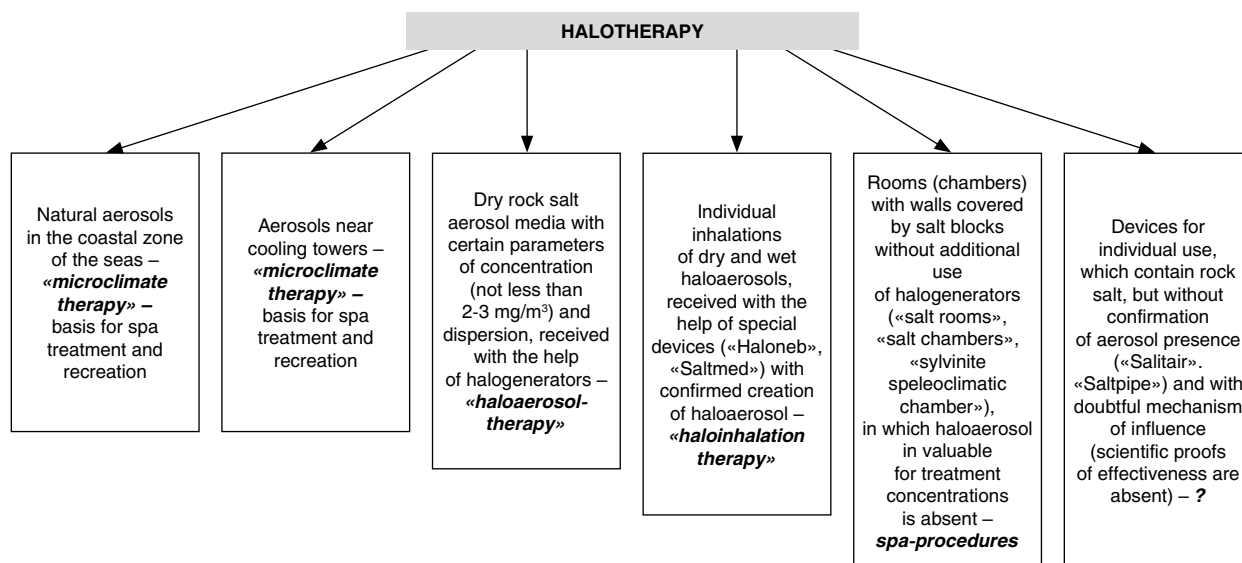


Fig. 1. Varieties of halotherapy

electrical charge than wet one and therefore its effect on the bronchial mucosa is more significant [11, 21, 23]. It is also believed that particles of dry haloaerosol due to high surface energy and forces of electrostatic interaction contribute to cleaning the air from microorganisms, allergens and other air dirt particles, thus forming a hypobacterial and hypoallergenic environment in the treatment rooms [7, 21]. It has been proved that the efficiency of air purification depends on the concentration of the haloaerosols and increases directly according to this parameter [23].

In addition, it is calculated that a dose of sodium chloride, which is received by the patient within one hour of the procedure with the use of dry haloaerosol, is much lower than that in inhalation of wet aerosol [11]. Polish researchers calculated that within 1 hour of the procedure with dry haloaerosol with the concentration of 10–15 mg/m³, the patient on average receives only 13 mg of sodium chloride, which can not have a negative effect on the organism of the patient as a whole [37]. Although, it should be noted that when the concentration of haloaerosol increases, a dose of sodium chloride, which the patient receives, may increase.

The next part of the review will highlight the main components of the mechanism of influence of this method of recovery treatment and the peculiarities of its use for different nosologies as well as the analysis of its effectiveness.

In addition, there is the term «haloinhalation therapy» (HIT), which is used in describing devices for individual inhalations with sodium chloride solutions or dry rock salt aerosol. In the available literature, we could find data on the effectiveness of using two types of individual inhalers to create dry rock salt aerosols: «Haloneb» designed by the researchers of St. Petersburg and «SaltMed», developed by the «TehnoBionic» company (Romania) [13, 36]. «Haloneb» can work in two modes: 0,4–0,6 mg of haloaerosol for 1 minute and 0,8–1,2 mg/min, producing mainly a highly dispersed fraction of haloaerosol (1–5 µm) (more than 90% of its fractional composition) [11]. The use of this method is recommended for adults and children, mainly at convalescence period of bronchial asthma, chronic and recurrent bronchitis, cystic fibrosis, some ENT-pathology, and is possible for use in acute bronchitis (12–20 procedures per treatment course) [1, 11, 22]. The effectiveness of this technology was proved on the basis of two studies, which included 74 and 126 patients with bronchial asthma [1, 22]. They evaluated the dynamics of clinical data, the results of spirometry and bronchodilator tests, laboratory indices of the activity of the inflammatory process, as well as changes in cellular composition of sputum [1]. The authors identified three types of patient response to HIT; the first type with a balneoreaction after 3–6 procedures (some worthening of clinical and functional data) occurred in 68% of patients. However, pronounced bronchospastic reactions that are characteristic for inhalations of hypertonic sodium chloride solutions were not registered. According to clinical observations, significant improvement of the drainage function of the bronchi was noted. In 7% of patients no pronounced positive dynamics was observed, which the authors explain by the

absence of mucociliary clearance disturbances in these patients. The data about recovery of β_2 -adrenoreceptors sensitivity by the end of the course of treatment are of particular interest, as it increases the effectiveness of basic therapy of the patients [1].

The positive effect of HIT is associated with normalization of rheological properties of sputum, activation of mucociliary clearance, anti-edematic effect on the bronchial mucosa and improvement of bronchial drainage in general [1].

In contrast, Romanian researchers propose using dry haloaerosol in the form of individual inhalations in patients with bronchial asthma and COPD during exacerbation [36]. The study was conducted at the Emergency Hospital in Bucharest and included 393 patients with exacerbation of bronchial asthma or COPD, 189 of which received standard therapy, and 204 – the same standard therapy in combination with HIT, carried out using the «SaltMed» device. The patients condition was controlled during one hour. Monitoring of respiratory rate, PaO₂ and PaCO₂, blood saturation was conducted. After 1 hour from the beginning of the treatment, the values of the studied indices reliably improved compared with the group that did not receive HIT and, importantly, there were no significant side effects of HIT. This made it possible to transfer at once the patients to the common therapeutic department, instead of the reanimation or the intensive care department. The achieved effect is explained by decrease in inflammatory edema and improved sputum release. However, there is no information on further course of disease at these patients, which requires appropriate research. Neither have the technological characteristics of the device used and the method of conducting the inhalations been specified.

Also, individual inhalations with hypertonic solutions of sodium chloride, which some of the authors also refer to as halotherapy, should be singled out. Most often, these inhalations are used in patients with cystic fibrosis [9, 27, 31, 40]. It is advisable to use solutions with a concentration of 3% to 12%, in most cases it is recommended to carry out inhalations 2–3 times a day, a course of treatment should last from 12 to 28 days. It has been demonstrated that within 8 hours after inhalation of 7% solution of sodium chloride there is a significant improvement in mucociliary clearance [30]. It has been proved that hypertonic solutions of sodium chloride not only improve mucociliary clearance, but also have anti-inflammatory and antibacterial effects, more effectively relieve manifestations of exacerbations, and promote improvement of ventilation data [27, 31, 35, 40, 41]. However, it has been noted that such inhalations can often (in 30% of cases) provoke cough intensification and cause bronchospasm. Therefore, inhalations of hypertonic sodium chloride solutions should be combined with the prescription of short-acting bronchodilators [35].

Recent studies have also demonstrated the effectiveness of using hypertonic sodium chloride solutions in bronchiolitis in children and in bronchiectases, not related to cystic fibrosis [40, 45, 48]. However, it should be noted that the

term «halotherapy» in relation to the inhalation of sodium chloride hypertonic solutions is used quite rarely.

On the contrary, the newfangled therapeutic methods («salt rooms», «salt caves», rooms of «live air»), using the authority of speleotherapy and haloaerosoltherapy, often refer to themselves as halotherapy or the so-called «artificial speleotherapy». However, they only pursue commercial goals. Their facilities have only a «medical design»: the walls are covered with salt and other comfortable conditions (backlight, music) are created, but the main acting factor — haloaerosol is not accounted). There are a number of studies that prove the inability of these methods as treatment technologies. It has been proved that in the case of haloaerosoltherapy the procedure rooms do not require to cover walls with salt [21], and the use of salt blocks does not provide the formation of highly dispersed rock salt aerosol [23, 26]. This can be illustrated by the example of the «sylvinite speleoclimatic chamber», the publications on which refer to various characteristics of the method, but ignore the question of the concentration of sylvinite haloaerosol. However, only in L.A. Verykhova's monograph «Speleotherapy in Russia» is clearly indicated the concentration of not more than 0,07 mg/m³. At the same time A.K. Obruch and S.K. Filipchuk (2001) indicate concentration of sylvinite haloaerosol of 0,19–0,25 mg/m³ [2, 14]. Although, beyond doubt, other factors (design of walls, purified air, etc.) can have a certain positive effect upon the patient, which justifies the indication of the treatment in «sylvinite speleoclimatic chambers» for patients with vegetative-vascular dystonia and chronic fatigue syndrome [16]. It is precisely the absence of appropriate haloaerosol concentrations that explains a variety of treatment regimed in these chambers. In particular, for children, the procedure can take from 1 to 10 hours, while using a haloaerosoltherapy with appropriate haloaerosol concentrations takes from 15 to 30 minutes, depending on the age. Belarussian researchers also indicate low concentrations of haloaerosol in «salt rooms» (0,2–0,43 mg/m³) [10].

Notably, with the use of halogenerators, it is possible to achieve a haloaerosol concentration up to 500 mg/m³, although such high concentrations are not used [26]. In «salt rooms», in addition to very low concentrations of haloaerosol (less than 2 mg/m³), the disperse phase of such aerosol consists mainly of particles of less than 1 µm. Thus, this treatment can not provide therapeutic effect, since these particles are not stay on in the bronchopulmonary system [12, 34, 36, 47].

According to Romanian researchers, in «Halotherapy salon», which is made of special blocks of rock salt in case when halogenator does not work the concentration of haloaerosol reaches only 0,4–0,7 mg/m³, while the content of particles of the disperse phase of 0,5–2,0 µm is 87–90%, and the size of the others does not exceed 2,5–3 µm [42]. That is, a clinically significant hyperosmolar stimulus is questionable. With an additional work of the halogenerator the concentration of haloaerosol reaches therapeutic values.

The works of Polish scientists concerning the concentration of haloaerosol and the chemical composition of salt

in various methods of halotherapy are of extremely great interest. They have researched these concentrations on the coast of the Baltic Sea, near the cooling towers, in the speleotherapy departments of Wieliczka, Bochnia and K odawa, and in the «salt rooms» on the surface with and without the halogenerator [26, 37]. The researchers have proved that covering walls with salt does not provide the formation of an appropriate concentrations haloaerosol, reaching only 0,5–1,4 mg/m³, while the volumes of underground salt production, where natural haloaerosol is forming (tens of thousands of m³), can not compare with any structure on the surface. Nevertheless, researchers point out that in urban conditions, with appropriate accompanying factors (quiet calm music, backlighting, comfortable resting place), «salt rooms (chambers)» can be used for relaxation as a spa procedure [37, 47].

The ineffectiveness of «salt rooms» without the use of a halogenerator for treatment of bronchopulmonary pathology has also been demonstrated in a randomized, double-blind study in children with asthma [25]. Children were divided into two subgroups: one received halotherapy using a halogenerator, and the other without one. The researchers evaluated bronchial hyperreactivity, level of nitrogen oxide in the exhaled air (FeNO) and quality of life with the help of the PAQLQ. The course of treatment consisted of 14 procedures. At the end of the treatment in the first group, significant positive changes were noted for most of these indices. In the second group, in the treatment of which the halogenerator was not used, no significant changes were registered.

Even more disputable is the issue of using such devices as «Salitair», «Saltpipe» and their analogues. These devices are plastic inhalers for individual use, containing salt, the particles of which enter the respiratory tract during inhale. But there was no information that would confirm the formation of such aerosol and its characteristics. One can only predict that the intensity of the haloaerosol effect (if any) will depend very much on the functional state of the bronchopulmonary system as a whole and the inspiration intensity in particular.

There are data about two clinical investigations of the effectiveness of the «Salitair» inhaler (both from Iran). The first concerns a 2-month treatment of patients with bronchoectasis not associated with cystic fibrosis with the «Salitair» inhaler [38]. The authors examined 20 patients with bronchoectasis before and after the treatment (6-minute walking test, spirometry and quality of life questionnaire SF-36). At the end of the treatment, researchers did not register significant changes in functional data and quality of life indices, although undesirable side effects were not detected either. However, 65% of patients were satisfied with the treatment and agreed to further use of the inhaler.

The second study concerned patients with COPD and was placebo-controlled [32]. 84 patients were examined, the spectrum of the studies included a 6-minute walk test, an assessment of blood saturation, a COPD assessment test (CAT) and spirometry. After two months of treatment, positive changes were noted in the 6-minute walk

test, but changes in CAT and external respiratory function were not recorded. On the basis of these results, the authors concluded that the feasibility of using the «Salitair» inhaler in patients with COPD was doubtful and requires further research.

Conclusions. Thus, the use of the term «speleotherapy» for any medical procedures performed on the surface of the earth is incorrect and indicates an poor professional level of such publications.

To date, the term «halotherapy», which indicates the type of a therapeutic procedure using dry rock salt aerosol, has lost its significance. The use of dry rock salt aerosol media with a certain concentration of haloaerosol (not less than 2–3 mg/m³) and the corresponding characteristics of dispersion in the form of group inhalation should be termed «haloaerosoltherapy». In publications on this method of treatment, it is necessary to specify the

concentration and dispersion of haloaerosol, the duration of the procedures, their number in the course of treatment and the regime of prescription. Without such data, any analysis and effectiveness evaluation is incorrect.

When carrying out individual inhalations with dry rock salt aerosol, the term «haloinhalation therapy» should be used. In this case, technical characteristics of the device (inhaler) must be provided, which would confirm the formation of such haloaerosol and its characteristics. These data should be indicated in any publication on the use of this method of treatment. Only in this case, it is possible to clearly distinguish true methods of treatment from various spa procedures and other manipulations that do not and can not have therapeutic effect. Exactly depending on doctors' understanding of this situation correct use of these methods is possible.

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