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REVIEW

POST COVID-19 PATIENTS' REHABILITATION – POTENTIAL OF USING HALOTHERAPY IN THE FORM OF GENERALLY ACCESSIBLE INHALATORIA WITH DRY SALT AEROSOL

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Abstract: In the times of the ongoing COVID-19 pandemic and related cases of coronavirus infection with its complications affecting patients effective ways to relieve these symptoms are being searched. The article presents a review of publications on the effectiveness of inhalation with dry salt aerosol, one of the forms of halotherapy, in relation to the alleviation of symptoms of chronic respiratory diseases which often coincide with symptoms after COVID-19. The results of the analyzed studies show the effectiveness of halotherapy in the indicated form in relieving the symptoms of respiratory diseases such as dyspnoea or cough. More and more popular in Poland generally accessible inhalatoria with a dry salt aerosol can be considered as part of rehabilitation for patients after COVID-19.

Keywords: COVID-19, rehabilitation, sodium chloride, inhalation, dry powder inhalers, respiratory therapy

In recent years 3 external inhalatoria (or inhalation 'spaces') with dry salt aerosol financed by the Civic Budget were built in Warsaw. Dry salt aerosol inhalations are a type of halotherapy, i.e. therapy in which salt is used in various forms for therapeutic purposes. Clinical studies show the effectiveness of dry salt aerosol against common chronic respiratory diseases. Due to the ongoing pandemic of COVID-19 and related cases of coronavirus infection with its complications affecting patients effective ways to relieve these symptoms are being searched. The most frequently reported long-term respiratory symptoms are cough and shortness of breath or difficulties in breathing. According to the analyzed studies, halotherapy in the form of inhalation with dry salt aerosol is effective in relieving these types of symptoms. External inhalatoria with dry salt aerosol are most often located in parks or other green areas, as well as in the hospitals or other medical facilities area (e.g. the planned investment of building an external dry salt inhalatorium at the Masovian Provincial Hospital in Rudka or just finished investment in Suprasl health resort in Podlasie). This creates great opportunities in terms of the availability of therapy for practically all members of the local community. The therapy is believed to be safe due to the use of a natural substance which is sodium chloride.

COVID-19

Epidemiology and description of the disease

The SARS-CoV-2 virus is a typical animal-derived virus responsible for the COVID-19 disease. The disease is classified in the group of zoonoses, which includes the vast majority of human diseases. Transmission of pathogens from animals to humans and from humans to animals is a natural part of the biological cycle. The first case of the disease in the world was reported in December 2019 in the city of Wuhan from the Chinese province of Hubei, and the first confirmed case in Poland appeared on March 4, 2020. Research results show that COVID-19 spreads in all known geographic conditions, which is the reason for such a rapid and global expansion of the disease (1).

Coronavirus penetrates inside the cells of the body by interacting with specific proteins, the presence of which is found in various tissues and organs

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of our body, in particular, on the cells of the epithelium of the respiratory tract (mainly the nasopharyngeal cavity) and the endothelium of the pulmonary vessels. For this reason, the symptoms of SARS-CoV-2 infection mainly concern the respiratory system, however, the presence of proteins that allow the virus to penetrate into other organs enable the virus to cause damage outside the respiratory system as well (1).

There is still a lack of knowledge regarding the long-term impact of coronavirus infection on the human body. However, there is a high probability related to the long-term negative health effects of COVID-19, based on reports of recoveries with persistent respiratory symptoms after recovery. At this stage, it is not yet clear how long such changes may persist much less what effect they may have on individual organs. Importantly, even in patients who had been infected asymptomatically or very mildly, changes in the body cannot be ruled out - studies have shown that a large proportion of these patients had changes in the blood picture and abnormalities in the lung picture (1). Due to the relatively short presence of the disease in the population, it is difficult to determine the exact number of asymptomatic infections - however, it has been found that in about 75% of asymptomatic infections the disease develops at a later stage which is related to the lower respiratory tract infection by the virus. The symptoms of the disease are highly nonspecific and vary in severity. Based on data from China it has been estimated that in approx. 80% of cases the disease is mild, in approx. 15% is moderate or severe with possible hospitalization and oxygen support and in approx. 5% is severe requiring treatment in an intensive care unit (2). WHO provides similar data: in 81% of cases the disease is mild, while in 14% is severe requiring hospitalization and oxygen treatment, and in 5% it requires treatment in an intensive care unit (3).

The most common symptoms of COVID-19 established on the basis of the course of the disease are fever, cough, difficulty in breathing, and shortness of breath, features of bilateral interstitial pneumonia (2). WHO reports similar data on the symptoms of the disease, supplementing the list with muscle pains occurring in approximately 11% of affected patients.

Treatment of coronavirus infection depends on the severity of its course. Mild cases are treated symptomatically. Patients who develop pneumonia are treated with antiviral and/or immunomodulating medications while patients with respiratory failure are treated in an intensive care unit with respiratory support (1).

Long-term complications after COVID-19

Based on patients' reports respiratory and gastrointestinal or neurological symptoms were reported as long-term complications after COVID-19. A study by Tenforde et al. (4) conducted among US patients 2-3 weeks after a positive COVID-19 test showed the following symptoms: fatigue, cough, shortness of breath, loss of taste or smell, headache, diarrhea, nausea, chest pain, stomach pain, confusion. Post disease complications occurred also in young adults and children without comorbid chronic diseases. High blood pressure, obesity, and mental disorders were considered as risk factors for the persistence of symptoms after recovery. Alberta Health Service (5) has conducted a review of studies on long-term symptoms after the COVID-19. Based on the review a list of 46 chronic symptoms following acute SARS-CoV-2 infection was developed. Among the most frequently reported in the analyzed studies were: dyspnea, fatigue, cough, headache, loss of smell (lack of smell), cognitive impairment, loss of taste (lack of taste), joint and muscle pain. Chronic sleep disturbances, chest pain, tachycardia, gastrointestinal disturbances, muscle weakness, and restlessness have been reported less frequently. Similar symptoms are indicated by Ordog's study (6) completing the list among others about the shortness of breath or difficulty in breathing, inability to exercise, or memory problems.

In conclusion, the most common respiratory symptoms after COVID-19 (dyspnea, shortness of breath, cough; often associated with residual mucus in the respiratory system) are characteristic for many chronic diseases of the respiratory system. These types of symptoms significantly reduce the patient's quality of life, limiting his daily activity, making it difficult or sometimes impossible to perform daily activities, work, etc. It can be caused by various types of chronic diseases such as asthma, bronchitis, pneumonia, chronic obstructive pulmonary disease (COPD), etc. (7).

Rehabilitation of patients after COVID-19

Currently used methods of rehabilitation after COVID-19 available under the National Health Fund

The current recommendations for the rehabilitation of patients after COVID-19 are included in the Regulation of the Minister of Health of 13 July 2020 on a pilot program in the field of therapeutic rehabilitation for recipients after COVID-19 disease (8). The assumed rehabilitation time is 21 days. Patients are referred to 1 of 5 models of respiratory physiotherapy based on the results of exercise tests.

The following services are provided (to a different extent depending on the model): cardio training, breathing exercises, station training, general improving exercises, techniques for removing secretions from the bronchial tree, inhalations, relaxation, optional psychological support, optional physical therapy treatments.

In terms of inhalation, i.e. point 6, inhalations are made with saline solution. Among the requirements for medical equipment and apparatus, an inhalatorium is required, in which inhalations will be performed with the use of bronchodilators, secretions thinning, and expectorants medications. Therefore, the services available from the National Health Fund in the field of inhalation are inhalation with saline and medications supporting the removal of secretions.

Halotherapy in the form of inhalation with dry salt aerosol

Halotherapy (Greek: halos means salt) is a treatment with the use of salt in various forms. One of the forms of halotherapy is inhalation with dry salt aerosol used in the treatment of respiratory diseases. Dry salt aerosol is in the form of crystalline dust or powder with very small particle sizes (1-5 μm) which allows it to reach the deepest parts of the respiratory system (9).

Thanks to the strong hygroscopic properties of salt the dry aerosol microparticles in the humid environment of the respiratory tract change their physical state from solid to liquid and deposit in the bronchioles and alveoli in the form of fine saline droplets. Dry salt aerosol causes secretolysis (the mucus thinning) making it easier to expectorate. The presence of sodium chloride promotes the work of the cilia facilitating the separation of sputum and reducing its viscosity (9). Dry salt aerosol has been shown to improve the cleansing function of the nasal mucosa (mucociliary clearance) as well as restore the nasal drainage function. Additionally, it has anti-swelling and anti-inflammatory properties on the mucosa (10).

The effectiveness of dry salt aerosol in relation to respiratory diseases – literature review

Selected publications on the effectiveness of inhalation with dry salt aerosol in the treatment and rehabilitation of respiratory diseases were analyzed. For this purpose, the following databases were searched:

– Google Scholar - the following search terms were used: „halotherapy dry salt aerosol" and „halotherapy clinical studies". 5 publications were found and included in the analysis.
– PubMed –the following search query was formulated: ((((halotherapy) OR (dry salt powder)) OR (NaCl aerosol)) OR (salt therapy)) AND (inhalation). Additionally, the time filter was marked: 2000-2021. In response to the above inquiry, 692 publications were received. Only studies related to halotherapy in the form of inhalation with dry salt aerosol were included in the review - according to this criterion 16 publications were selected and analyzed.

The available publications on the use of inhalation with dry salt aerosol in relation to diseases of the respiratory system have shown effectiveness in relation to the indicated disease symptoms occurring in chronic diseases of the respiratory system. The following considerations may be an introduction to conducting in-depth analyzes of the effectiveness of dry salt aerosol in relieving respiratory symptoms after suffering from COVID-19.

The study by Graepler-Mainka et al. (11) showed thinning and easier mucus secretion after one hour of inhalation with dry salt aerosol in patients suffering from cystic fibrosis. After 5 days of therapy a significant improvement in lung function parameters, an increase in the number of leukocytes, and improvement in the microflora of the mucosa were noted. Similar conclusions are also shown in the study by Oprita et al. (12) in which hospital patients admitted due to exacerbation of symptoms of bronchial asthma or COPD were examined. In addition to standard treatment, some patients were inhaled with dry salt aerosol. The parameters of oxygen partial pressure, carbon dioxide partial pressure, saturation, and respiratory frequency were compared. It is worth noting that the group additionally treated with dry salt aerosol inhalations included elderly patients with worse baseline parameters compared to the group receiving only basic treatment. After the end of all inhalation treatment cycles, the study group saw a significant improvement in all 4 analyzed parameters compared to the baseline values. Riethmüller (13) who uses halotherapy in children suffering from cystic fibrosis at the Children's Hospital in Tübingen writes about the positive effects of inhalation in the form of thinning and easier removal of residual mucus. Crisan-Dabija and Mihaescu (14) investigated the effect on the quality of life after using dry salt aerosol in patients with asthma and COPD. Within 12 months after the end of treatment with inhalations, a significant improvement in the quality of life was observed in a form of greater breathing comfort, reduction of dyspnea, and reduction of limitations in performing daily activities occurring before treatment. On the other

hand, in the study by Chervinskaya (15), long-term tobacco smokers reporting a smoker's cough were examined. Positive effects of salt inhalation in the form of mucus thinning (secretolysis) and reduced cough were noted in 88% of the patients. A significant decrease in the number and colonization activity of harmful pathogens in the respiratory tract (including S. pneumoniae, H. influenzae, S. aureus) was also observed in patients with a simultaneous increase in the number of bacteria in the natural mucosa microflora.

Based on the analyzed publications the following conclusions were made:

- Dry salt aerosol has bactericidal properties in the respiratory tract and increases the activity of phagocytes (phagocytes responsible for absorbing microorganisms). Additionally, it may reduce the incidence of inflammation of the respiratory tract (16-18).
- Inhalations with dry salt aerosol improve various parameters of lung function, including forced expiratory volume in one second (the volume of air being blown out of the lungs in the first second of forced exhalation), forced vital capacity (the largest volume of air that can be blown out of the lungs with maximum, rapid exhalation) and peak expiratory flow (the maximum airflow speed that can be obtained on exhalation) (16, 19).
- Dry salt aerosol improves the quality of life of patients with respiratory disorders (18, 19).
- Dry salt aerosol improves mucociliary transport (the natural defense and cleansing mechanism of the respiratory tract against inhaled microorganisms and harmful compounds) and lung function in common chronic respiratory diseases (17, 19-21).
- A significant reduction in the frequency of acute respiratory infections after inhalation with dry salt aerosol has been demonstrated in patients with stage I of COPD (22).
- The effect of dry salt aerosol has been shown to decrease the frequency and severity of cough and easier expectoration of mucus in patients with COPD (21).
- The best results are achieved by inhalations carried out over a period of 10-14 consecutive days (17, 19).

According to the authors of three publications (18, 23, 24), the need for more detailed studies with a larger study group was noted in order to confirm the effectiveness of the method. It is worth noting that halotherapy is a method that uses a substance natural for the body - sodium chloride which makes it safe to use. No side effects or negative reactions to the treatment were reported in any of the analyzed studies.

The presented review aims to show the effectiveness of dry salt aerosol in relieving symptoms of chronic respiratory diseases and considering the use of this method also in the rehabilitation of patients after COVID-19. Due to the relatively short presence of the disease in the population, no studies have been conducted on the use of halotherapy in the rehabilitation of patients with COVID-19. However, the convergence of symptoms that accompany chronic respiratory diseases with those of COVID-19 allows us to suppose that inhalation with dry salt aerosol could bring relief to many patients struggling with bothersome symptoms after suffering from this disease.

Possibilities of using publicly available dry salt aerosol inhalatoria in the rehabilitation of patients after COVID-19

Until recently, inhalations with dry salt aerosol were performed only in inhalation rooms in medical and paramedical facilities, with the use of a special medical device spraying salt dust. In May 2019, the first open-air, generally accessible inhalatorium with a dry salt aerosol was opened in Warsaw. Inhalatorium also uses a medical device that produces an aerosol, moreover, thanks to the use of a special system stabilizing the parameters of temperature and humidity of the air supplied from outside, the inhalatorium can operate all year round, regardless of weather conditions. Inhalatorium is located in the Wola district of Warsaw, in the Sowinski Park. In 2020, 2 more facilities of this type were completed in Warsaw, and in 2022, construction of another 3 inhalatoria is planned. All the above investments are financed under the Warsaw Civic Budget.

Interest in this form reached beyond Warsaw - recently completed investment in the Suprasl health resort or construction of inhalatorium planned in 2022 at the Masovian Provincial Hospital in Rudka and in Silesia in the city of Bytom.

The new form of dry salt aerosol inhalatoria significantly increases the availability of therapy for almost all members of the local community. Due to the short presence of the COVID-19 disease in the population, there are no studies yet on the possibility and effectiveness of using dry salt aerosol inhalation in rehabilitation after COVID-19. However, the similarity of symptoms with other chronic respiratory diseases and the available publications on the high effectiveness of dry aerosol in alleviating

symptoms of these diseases suggest that the therapy could also be used in the case of COVID-19. For this purpose, the authors reviewed the publications available on the topic, the results of which are presented below.

Publicly accessible dry salt aerosol inhalatoria as a potential element of rehabilitation of patients after COVID-19

Until recently halotherapy in the form of inhalation with dry salt aerosol could only be used in closed health-promoting facilities. In recent years generally accessible inhalatoria with dry salt aerosol located in publicly accessible places, e.g. parks or hospitals have become an increasingly popular form. This form of therapy certainly has enormous potential in terms of accessibility for a large group of patients. The first external inhalatorium using dry salt aerosol in the world was built in the Warsaw district of Wola, in Sowinski Park in 2019 (25). The next two inhalatoria were built in 2020 in the districts of Wawer (26) and Targowek (27). Both the inhalatoria in Wola and the other two were implemented under the Civic Budget of Warsaw. At present these are the only outdoor generally accessible halotherapy facilities in the form of dry salt aerosol existing in Poland. Currently, further facilities of this type are planned also outside Warsaw, eg the planned investment of building an external dry salt aerosol inhalatorium at the Masovian Provincial Hospital in Rudka or just finished investment in Suprasl health resort.

On the basis of the already constructed buildings, it is possible to define external dry salt aerosol inhalatorium as free-standing, roofed, wooden structures, semi-open and circular. In the central point, there is a technical room in which a medical device (Device registered by the Office for Registration of Medicinal Products, Medical Devices and Biocidal Products with a medical certificate of a body notified by the Ministry of Health) producing salt aerosol from dry salt is installed. The use of an innovative method of producing dry salt aerosol in changing weather conditions allows the inhalatorium to work throughout the year. The aerosol is distributed inside the inhalatorium where the patients walk. At this point, it is worth noting that moderate physical activity during inhalation, e.g. walking, is necessary to maximize the positive effects. In a static position (sitting or lying down) we breathe shallow, at the top. Light physical activity in the form of, for example, walking, forces the deepening of the breath, which is important from the point of view of the deposition of aerosol particles - during a deep, calm breath, 50-80% of the aerosol is deposited in the respiratory system (28). The form of a circle that allows for a walk inside the inhalatory space causes deepening of the breath maximizing the positive effect of inhalation.

The effectiveness of halotherapy in a form of inhalation demonstrated in studies on relieving symptoms encourages deepening research towards the possibility of using this therapy on a wider scale in patients after COVID-19. Inhalations can take place both indoors and outdoors, in external inhalatoria. The form of external inhalatoria can significantly increase the availability, which will enable all those in need to benefit from the therapy. The therapy can be used by children, adults, and seniors, as well as people with disabilities, e.g. in a wheelchair. A potential threat may be, for example, irregular or too short use of inhalation by individual people. In order for inhalations to be effective, they should be carried out for about 10-14 consecutive days for 30-60 minutes. This problem can be partially solved by educational boards present in inhalatorium teaching how to use inhalation properly. Another solution may be educational campaigns organized by the commune or city office addressed to the inhabitants of a given region who are potential users of the external inhalatoria. Another possible solution is to organize the enrollment of individual people or groups for the so-called 10 or 14-day „stay". This creates additional opportunities to conduct evaluation questionnaires for patients after the inhalation stay.

In the time of the COVID-19 pandemic, there is undoubtedly a question about the safety of using public facilities. As in the case of other public facilities, it requires proper organization, e.g. by inhaling people living together or one school class or kindergarten group at the same time. Based on already functioning inhalatoria it is known that each inhalation cycle is followed by an automatic 15-minute ventilation cycle during which airing and air exchange inside the inhalatorium takes place. After a ventilation cycle, another group can have inhalation cycle. Room ventilation is one of the Chief Sanitary Inspectorate, Ministry of Health, and Ministry of Education Guidelines for primary schools on limiting the spread of COVID-19 (29).

Another technical issue is to ensure hygiene standards in terms of protection against the presence of, for example, the homeless while the inhalatorium does not work. Based on the existing facilities it is known that a technical person is employed who starts and monitors the facility during its use and after finishing the work it is closed with a special door and a padlock.

Summary

Based on the above considerations it can be concluded that generally, available inhalatoria can complement rehabilitation for patients after suffering from coronavirus infection. The lack of scientific evidence of the use of this method in relation to COVID-19 patients is due to the short presence of the disease in the population. However, the convergence of symptoms with other common chronic respiratory diseases in relation to which the effectiveness of halotherapy has been demonstrated allows for a thesis about possible effectiveness also in this indication.

Respiratory symptoms such as dyspnea, shortness of breath, difficulties in breathing, cough are often associated with residual mucus in the respiratory system resulting in limitation of daily activity and having an extremely strong impact on the patient's quality of life. Reduced quality of life affects mental well-being, professional and family activity, etc. For this reason, it is so important to take all measures to improve it by providing patients with effective methods of relieving troublesome symptoms.

Conflicts of interest

The author declares that he has no conflict of interest.

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