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

Key words: *speleotherapy, definition, history of development, mechanisms of influence, effectiveness. «Natura sanat, medicus curat».*

Treatment of patients with chronic pathologies, including pulmonary pathology, involves both treatment in the acute phase and certain medical procedures beyond the acute period aimed primarily at maximizing remission, prevention of further exacerbations and complete functional recovery of patients, which is the basis for improving the quality of life [51, 63, 74]. This led to the introduction of the concept of pulmonary rehabilitation and the approval of the provision (recommendations) for its implementation, especially in patients with COPD, which include physical training, educational program, correction of nutritional status, consultation of a psychologist, which is undoubtedly of great importance [47]. However, the issue of other non-pharmacological therapies (physiotherapy or spa treatment) traditionally used in Eastern and Central Europe has been given less attention. The situation changed with the revision of the Regulation on pulmonary rehabilitation (common to ATS and ERS) in 2013. The updated definition clearly stated that pulmonary rehabilitation is a set of methods that include, but are not limited to, the above therapies in patients with chronic respiratory diseases in general [56]. The document also emphasizes the need for scientific research of the mechanisms of the effect of rehabilitation technologies. In this regard, the question arises about conducting a pragmatic analysis of existing developments in the field of pulmonary rehabilitation, confirmation of the validity and appropriateness of their use, definition and concretization of indications and contraindications for their application.

One of the possible methods for pulmonary rehabilitation is the use of speleotherapy, halotherapy and haloaerosoltherapy; however, there is no clear conception of these methods among the majority of the medical community, which results in incorrect assessment and lack of understanding of the difference between medical treatment and spa procedures.

The aim of the study is to give an analysis of available developments in the field of speleotherapy, halotherapy and haloaerosolterapy, and the validity of the indications for their application, to distinguish between medical and spa use of certain methods and to determine the prospects for their further use.

One comment in the Appendix to the Order of the Ministry of Health of Ukraine No. 555, June 27, 2013 «Chronic Obstructive Pulmonary Disease. Adapted Clinical Evidence based Instruction» [9] categorically states that spa treatment is not included in the list of health services provided by the healthcare system in the EU and the USA. Therefore, there is no scientific assessment or studies in these countries regarding the impact of non-pharmacological and spa-related factors on human health. However, the situation is not so straightforward. Firstly, there are a number of publications on this issue in the European Respiratory Journal (including those published in the last 5 years), the International Journal of Respiratory and Pulmonary Medicine, Balneologia Polska, Balneo Research Journal (Romania), Journal of Cystic Fibrosis (Germany), Alergie (Czech Republic), etc. Secondly, in some EU countries, particularly in Hungary and the Czech Republic, some types of rehabilitation and spa treatment for certain groups of patients are partly provided by the healthcare system. Therefore, accounting the existing potential of medical natural resources, an assessment of the situation regarding this issue is current in Ukraine.

Speleotherapy (from the Greek «speleon» – cave) is the use of karst caves and mine workings (silver, salt, potassium, lead, etc.) for curative purposes [32, 53, 68]. That is, in any case, this method of treatment supposes patients' staying in underground environment for a certain period of time (ranging from 2 to 12 hours a day, depending on the concrete speleotherapy clinic). The course of such treatment varies in most cases within 3-4 weeks. It should be emphasized that any procedures, either medical or recreational, which are carried out on the surface of the ground, can not be called speleotherapy or have, as some authors state, «speleotherapeutic effect».

There are only few references in literature [2, 68, 74] concerning spontaneous and primitive use of caves for curative purposes since the Middle Ages (Italy, Greece, Hungary, China, etc.), while the first written record of the curative effect of the salt mines of Wieliczka, Poland dates back to the 15th century [48]. However, this trend formed a branch of medical science only in the middle of the 20th century, when the therapeutic effect of the Klutert Cave in Germany at patients with bronchial asthma was noted. This cave used as a bomb shelter during the Second World War [69], and then became the first speleotherapeutic medical establishment in 1949.

The healing (curative, therapeutic) properties of both karst caves and various mine workings have been investigated [44, 52, 54]. However, speleotherapy in salt mines proved to be the most efficient, and the first medical department in a salt mine was opened in 1958 in Wieliczka near Krakow, Poland [63].

Speleotherapy in Ukraine (and in the former Soviet Union) appeared due to the initiative of the head of the Transcarpathian Regional Council V.P. Rusyn in 1968, when the first speleotherapy department and later the regional and republican (now Ukrainian) allergological hospitals opened on the basis of the district hospital in Solotvyno, Transcarpathian region. Already by 1990s, based on the experience of speleotherapy in Solotvyno, medical treatment was developed in other speleological hospitals, such as: Chon-Tuz (Kyrgyzstan), Nakhichevan (Azerbaijan), Berezniki (Perm, Russia), Salihorsk (Belarus). Speleotherapy in the karst cave was conducted in the Tetri Mgvime (Tetri Cave) in Georgia, where a speleological hospital was opened in 1979 for the rehabilitation of patients with bronchial asthma and chronic bronchitis [72].

Various underground objects of natural or anthropogenic origin with very diverse microclimatic characteristics can be used for curative purposes. In particular, caves with a temperature of 6-15°C and a humidity of 80-100 % prevail among the karst caves [68, 74]. The main parameters of air, beside high humidity and low (uncomfortable) temperature, are high calcium and magnesium, electronegative aeroions content, and the absence of bacteria, fungi, candida and allergens common to the surface of the ground [39, 52, 55, 66, 74].

A number of authors pay great attention to the presence of radon and thorium in caves and the associated certain elevated radioactivity [38, 41, 65, 71]. Others focus on the presence of geoaerosol, negative charged ions and high content of carbon dioxide [42, 46, 74]. According to researchers, inhalation of calcium ions has an anti-inflammatory effect, and high content of magnesium promotes relaxation of bronchial muscles. The inhalation of the humid air of the karst caves leads to increased hydration of the damaged epithelium and the dissolution of mucus in the respiratory tract, and the negative air ions promote improved regeneration and increased activity of the ciliary epithelium, which leads to the cleaning of the bronchi and increases their permeability. Particular emphasis is given to the importance of self-cleaning of the cave environment and maintaining its stable parameters, regardless of the climate and weather conditions on the surface [52, 55, 66].

Microclimatic conditions in different mine workings are not less diverse [20]. The air temperatures vary widely: in the salt mines from 13 °C in Berezniki (the Russian Federation) to 22-23°C in the Kinga mine (Poland), and in the Bad Gastein silver mine (Austria) the temperature reaches 38-41°C. Relative humidity in most mines is lower than in karst caves and reaches 30-80 %. The high radiation background is recorded predominantly in potash mines, and in salt mines it is lower than the usual level for a given area. The Bad Gastein silver mine combines hyperthermia (up to 41°C) with elevated radon levels. According to researchers, such a combination effectively stimulates the protective and adaptive functions of the body, the pituitary-adrenal system and increases the rate of enzymatic reactions, as well as normalizes the activity of the autonomic nervous system [43].

It should be emphasized that in the salt mines an aerosol of rock salt (haloaerosol) is present, while in others (lead, silver mines) it is absent. In addition, among the additional chemical elements contained in haloaerosol, there are magnesium, manganese, silicon, iron, aluminum, calcium, vanadium, titanium, copper in concentrations from 0.01 to 0.0003 %, which, in combination with a certain structure and morphology of crystals of salt, promotes high biological activity of curative rock salt aerosol [5]. It has also been also demonstrated that the presence of clay components in salt mine rocks can give them sorption properties, which is important in ensuring the stability and self-purifying capacity of the underground department [5].

However, despite the great diversity of microclimatic characteristics, all speleotherapeutic establishments have the following common features:

- stability of microclimatic and geoaerosol characteristics for each of the objects that do not depend substantially on seasonal variations [2, 17, 21, 52, 67, 68];
- absence of allergens common for the surface of the earth [20, 67, 68, 74];
- a low number of microorganisms in 1 m3 of the air (up to 70-100 in 1 m3) and the capability for self-purification within a few hours after the patients' stay [12, 15, 26, 29, 32, 36].

It should be noted that the microbiological control of the air environment and its change under the influence of anthropogenic loading is monitored in most speleotherapy facilities [1, 2, 12, 29, 32, 66]. In particular, the research by V.P. Kazankevych, V.V. Zheltvai et al. (1984) [12, 15]

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showed that the bacterial air pollution in the speleotherapy department of the Ukrainian Allergological Hospital (UAH) was 70 ± 3 microbes per 1 m3, it increased to 533 ± 16,6 microbes per 1 m3 during the treatment session, and was reduced to the initial level 4 hours after its completion. In addition, bacteriological study of sputum in patients with infectious-dependent inflammatory process was performed. It was proved that after the course of speleotherapy, the frequency of all microorganisms from sputum of patients decreased in 2.1-2.8 times, which explains the decrease in the activity of the infectious-mediated inflammatory process [11].

It is also worth noting that the effectiveness of treatment in various speleotherapy clinics is approximately the same regardless of the microclimatic parameters, and is determined by the nature of the nosology, its severity and the age of patients; in particular, in children it reaches 95 % [16, 20, 55, 57, 61, 74].

That is, the main mechanism of therapeutic effect of speleotherapy does not depend on a particular microclimatic index, but is determined by the general features that are characteristic of all speleotherapeutic facilities. Thus, the essence of speleotherapeutic influence is that due to isolation from the environment, stable microclimatic conditions, the absence of habitual pollutants and allergens in the air, low concentration of microorganisms reduces the irritation of the respiratory tract mucosa and inhibits the activity of the allergic and inflammatory process caused by infection [7, 8, 19, 30, 37, 40, 73].

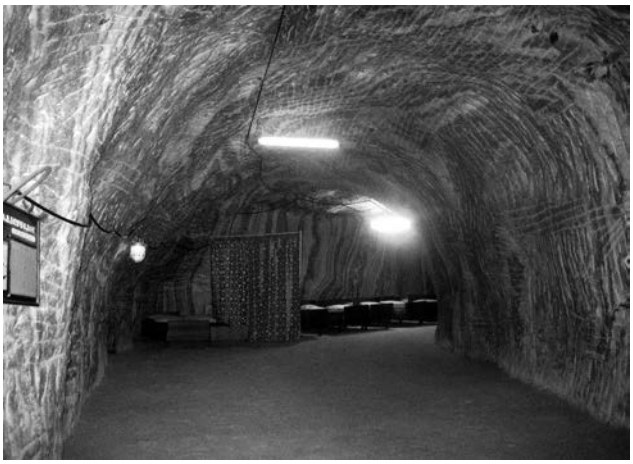
At the same time, descending under the ground and staying in unusual underground conditions causes prolonged «soft» stress for the organism, accompanied by activation of the adrenal cortex [14], which determines the anti-inflammatory effect, promotes the normalization of hormonal homeostasis [10, 14] and, besides reducing the intensity of the inflammatory process, causes a normalizing effect on the immune reactivity of the organism as a whole [3, 13, 22, 24, 45, 59]. These sanogenetic processes ultimately ensure stabilization of the disease duration and improve the quality of life of patients [16, 74]. Certain additional characteristics of the speleotherapeutic facilities (haloaerosol, temperature, elevated or decreased radiation background, etc.) determine only the details of the effect and the peculiarities of the treatment process.

The main general mechanisms of therapeutic influence of speleotherapy are confirmed by experimental investigations in laboratory animals and in clinical conditions in patients [5, 12, 15, 19, 40, 50, 66, 70]. Major experimental researches proving the effectiveness of the use of speleotherapy were conducted in Ukraine in the 1970-1980s and in Romania in 2001-2010. Today, most speleotherapy institutions conduct regular monitoring of microclimatic indices and carry out certain researches related to either the widening the indications for the use of a certain speleotherapeutic facility or the establishment of new speleotherapeutic facilities (Romania).

Considering the nearly five decades of experience of speleotherapy in Solotvyno and the achievements of our colleagues from Poland, the principles of a differentiated approach to speleotherapy indication have been defined, taking into account the peculiarities of a specific nosology, the presence of comorbidity, circadian rhythms, the age of the patient and other modifying factors [8, 17, 18, 19, 21, 34, 35]. It has been proved that speleotherapy reduced (improved) the sensitivity of the receptor apparatus of the bronchi prior to basic treatment, which increases its efficiency and allows to achieve better control over the course of the disease at patients with asthma [19]. Concrete

Мал. 1. **Карстова печера Ясовська, курорт Штос, Словаччина**

Мал. 2. **Соляна шахта міста Величка, Польща**



Мал. 3. **Підземне відділення УАЛ, смт. Солотвино (нині затоплене).**

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methods of complex treatment, which make it possible to strengthen bronchial drainage, have been developed [7].

The analysis of efficiency of repeated courses of speleotherapy with an interval of 9-12 months [23, 28] was carried out. Repeated courses of speleotherapy have been shown to enhance the positive clinical effect. Thus, according to a survey of patients with persistent asthma ranging from mild to moderate severity, remission for 9-24 months after the first treatment in UAH was observed in 55 % of patients, and after the second or third year – in 60 % and 74 % of patients accordingly. It should be noted that after the third course of speleotherapy asthma attacks were not observed throughout the observation period of 2 years in 42 % of patients.

The expediency of the use of speleotherapy to prevent the occurrence of dispnoea attacks in patients with conditions threatening the emergence of bronchial asthma [24] is substantiated. It has been proved that the inclusion of speleotherapy into the complex of other preventive measures with a duration of control up to 3-5 years decreases the frequency of the first attacks of bronchial asthma to 5-8 %, especially with repeated courses at intervals of 9-12 months. According to the literature, the use of other methods of medical and non-medicated (non-medicinal) treatment, the incidence of dispnoea attacks in this contingent of patients reaches 15-20 %.

It should also be noted that speleotherapy is used not only for the treatment of patients with chronic respiratory pathology and upper respiratory tract diseases. Indications for treatment in karst caves include rheumatic pathology (Bad-Gastein silver mine, Austria); besides, treatment of certain skin diseases (neurodermatitis, psoriasis) and reconvalescents after skin burns in salt mines has been proved efficient [6, 31, 33, 60].

Initially, the positive effect of speleotherapy on the above-mentioned skin lesions was noted in patients with bronchial asthma and concomitant neurodermatitis or psoriasis. Further studies have shown that in patients with neurodermatitis, positive dynamics of skin manifestations was observed in almost 85 % of cases, and in one third of patients (31.3 %) they disappeared altogether [60]. The achieved effect is confirmed by changes in immunological parameters and is explained by the stimulating effect of speleotherapy on the function of the adrenal glands and the corresponding regulation of hormonal status. This provides anti-inflammatory effect, which is combined with the local healing effect of haloaerosol on the skin surface.

Special attention should be given to the effectiveness of the use of speleotherapy as a rehabilitation treatment in reconvalescents after skin burns of II-IIIIA-IIIB degrees and burns of the respiratory tract, which may be quite relevant in wartime. After rehabilitation, which included speleotherapy, in these patients the maturation of post-burn scars and scar fields improves, pain and itching decrease, the scars become more flat and mobile, pyoderma disappears, small wounds and trophic ulcers are healed, which improves joint mobility and reduction of contractures [6]. After the course of complex treatment using speleotherapy, the number of patients without contractures increases from 16 % to 42 %, while the number of patients with contractures of one joint decreases from 30 % to 18 % and with contractures of 2-3 joints decreases from 50 % to 40 % of cases.

However, despite the achievements of our doctors and scientists, speleotherapy usage is very limited in Ukraine. Due to terrible mismanagement, the production facilities of Solotvyno salt mine was flooded in 2010. The speleo establishment in Soledar city, Donetsk region, was in operation only from 1993 to 2002. In 2007, the work of the spa was renovated, but it eventually stopped because of active military actions. Today, considering the situation in the Donbass area, there is no prospect for this establishment. There has been no precise study of the peculiarities of the work of this spa in the available literature. Among the indications for treatment in this institution diseases of the thyroid gland were included, while the course of treatment was reduced to 12-13 days [25, 27], which is the base for some query. However, scientific research on this subject has not been found.

The restoration of the work of Solotvyno salt mine requires significant investment, but the feasibility of an alternative to the Bakhmut deposit of rock salt, at least from economic perspective, is obvious. There is potential for the development of speleotherapy in karst caves, which requires less financial costs. The procedure of a comprehensive assessment of underground facilities that can be used for therapeutic purposes has already been developed [20, 49, 58]. It includes the solution of complex technical tasks in the first place, and then medical tasks. The technical tasks should include the study of physico-chemical properties and structure of the rock [20], and special attention should be paid on the compliance with mining specifications, the latter including the following:

- ventilation of underground workings, which has to provide the volume of air needed for a certain number of patients without violating the stability of air environment;
- compliance with all safety requirements for patients and medical staff;
- development of ways and methods of evacuation of patients and medical staff in emergency conditions.

At the intersection of technical and medical tasks is the study of microclimate of the underground facilities, which include the analysis of the composition of the air environment and the peculiarities of its regeneration, monitoring of the temperature, humidity, microbial contamination with the determination of the regeneration time of the air. The medical part of the program includes the definition of indications and contraindications for the treatment, the organization of the therapeutic process on the surface and in the speleotherapy department, which is special (specific) for each speleotherapeutic clinic. It is necessary to determine the duration of each treatment session and treatment variants of varying intensity depending on the nosology, its severity and other modifying factors. Medical issues also include monitoring the patient's state of health in the process of treatment and the organization of emergency care in the underground department.

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The influence of anthropogenic load on speleotherapeutic facilities has been studied, the criteria of its evaluation have been developed, and the necessity of regular cleaning of underground medical facilities has been proved [5]. It has been shown that in the process of therapeutic use of speleotherapeutic facilities in salt mines dusting of walls up to 2 m in height and thickness up to 3 mm takes place with the formation of secondary forms of crystals. This decreases the stabilizing potential of underground medical facilities, reduces the purity of the underground environment and determines the need for regular cleaning of the walls of speleotherapeutic department.

Despite all the failures and constraints, speleotherapy continues to develop successfully in the neighboring countries. In Romania, 3 new speleotherapeutic clinics were opened, comprehensive surveys, experimental work and analysis of clinical data were performed [38, 41, 46, 65, 73]. All these works were funded by the EU grants. A new speleotherapeutic department was opened in the salt mines of Bochnia (Poland), extensive physical and chemical studies of various types of rock salt used for therapeutic purposes were conducted [64].

According to the Heilstollen Association, there are currently 15 institutions in Germany, where speleotherapy is carried out in karst caves or salt mines. In 2006 a doctoral thesis was defended at the Faculty of Medicine of the University of Ulm on the effectiveness of speleotherapy in the treatment of bronchial obstruction in children [62]. This thesis contained a controlled, randomized and multicenter study based on clinical and functional parameters, and statistically clearly demonstrated the effectiveness of speleotherapy in children.

It should be emphasized that speleotherapy as a natural method of treatment, in contrast to medication, provides multicomponent effect on the organism, realized in the ways familiar to the human organism, which were developed in the process of human evolution. Moreover, speleotherapy is not characterized by allergic reactions, which often complicate medication. However, it is not opposed to basic pharmaceutical therapy; on the contrary, it is designed to supplement it organically and even increase the efficiency of complex treatment by improving (restoring) the sensitivity of the receptor apparatus.

Conclusions

Thus, the use of speleotherapy as a method of recovery treatment in patients with chronic non-specific pathology of the broncho-pulmonary system and the upper respiratory tract, especially bronchial asthma, chronic bronchitis, COPD, pancreas, etc., as well as certain skin diseases (neurodermatitis, psoriasis) is scientifically substantiated, testified by foreign experience. All the above places on the agenda the issue of a complete restoration of this method of rehabilitation in Ukraine, primarily on the basis of the Solotvyno rock salt deposit. However, taking into account possible incorrect use of speleotherapeutic facilities from the medical point of view, aimed at obtaining rapid financial profit (the so-called «speleotourism» and other forms of «business» use, non-compliance with the rules of anthropogenic load, violation of indications and contraindications for treatment and the corresponding methods of its conducting), it is necessary to ensure continuous monitoring of the implementation of the medical process in such institutions, both by specialists and the medical community as a whole.

In October 2018, we will celebrate the fiftieth anniversary of the launch of speleotherapy in Ukraine. There is hope that by that time, the issue of its restoration, at least in the form of some concrete plans, will start.

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