

Peter Oss

University Clinical Hospital

Anesthesiologist-resuscitator

Head of the Cabinet of Hyperbaric Medicine

## **Treatment of hypertension and oxygen**

Medically, such treatment is called hyperbaric oxygenation, abbreviated HBO.

### Definition

HBO is a method of treatment in which a patient breathes 100% oxygen (intermittently or continuously) in a chamber at elevated pressure above 1.0 atmospheres.

This treatment method is available at Pauls Stradins Clinical University and Riga East Clinical University Hospitals. Treatment is provided to both hospital patients and outpatients. Baroque cameras have been operating at Pauls Stradiņš University Clinical Hospital for more than 50 years, and a great deal of practical experience has been accumulated. HBO is recognized as an effective method for treating many diseases. In this article I would like to look at the development of HBO, the rationale and explain the usefulness of the method in some cases of pathology.

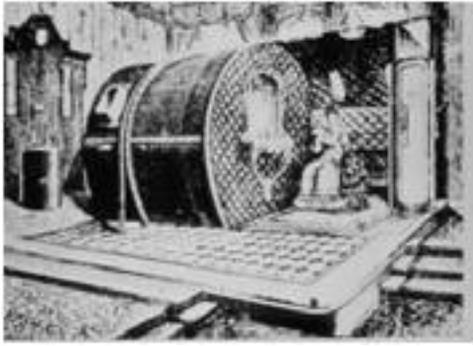
### About oxygen

Oxygen is a gas necessary for life. It is only less than 20% of the atmospheric air composition. Even less oxygen enters the human body, but we cannot do without it for five minutes. When breathing, oxygen enters the lungs. From the smaller structures of the lungs, the alveoli, it enters the bloodstream. The circulatory system delivers oxygen to the tissues through blood vessels through the bloodstream. Oxygen in the blood is mainly bound to hemoglobin, the main protein in red blood cells, but only a small fraction (2-3%) is dissolved in the blood. In tissues, oxygen is the substance that provides metabolism in cells. Here, energy and heat are produced from nutrients, and the function of life is maintained. More or less active metabolism is required in all organs. Oxygen consumption varies from organ to organ. It also depends on a person's physical and mental activity. However, if the oxygen supply becomes insufficient, the functioning of an individual organ or the whole organism is disrupted or even endangered. This condition can be termed the disease. Timely and effective restoration of oxygen supply can normalize metabolism. Most therapeutic measures in the treatment of diseases are aimed at this process. Of course, the ways to achieve these goals are varied, from lifestyle changes, medication use, various procedures to complex surgeries.

It has been found that oxygen is also used by white blood cells or leukocytes to fight microbes and bacteria that enter our body. It is a protective mechanism in case of infections. In wounds where the blood supply is weakened and the oxygen supply is insufficient, the healing process is delayed. Clinically, it is characterized by persistent wounds or ulcers.

### Air pressure chambers

Attempts to improve tissue blood circulation have been known in medical history since the 17th century. The English cleric and scientist Henshaw tried to treat the disease by placing patients in a high-pressure chamber. 1662 he constructed the first barricade (domicilium). Figure No.1. It turned out that the treatment was not successful and the method was forgotten for a long time.

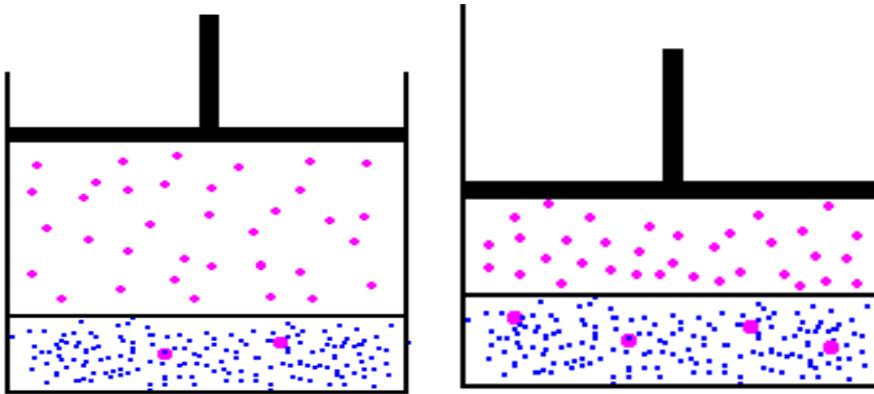


Picture no. B. Henshova barocamer-domicilium

The pressure on the dense tissues of the body has practically no effect. Oxygen was not used in the baroque chamber, it was filled with air. Oxygen in the air is not absorbed through the skin. Most of the air contains nitrogen, which is 78%, but it is not involved in the body's metabolism. From the 19th century, air pressure chambers were used to rescue and treat bridge and canal workers in cases of caisson or decompression sickness. Paul Bert (1878) was the first to discover the cause of caisson disease. When breathing air under high pressure (under water), the nitrogen in it is absorbed more into the blood plasma. Nitrogen levels in the blood increase. As you rise above the water, the pressure decreases. If the ascent is too rapid, the pressure drops rapidly and nitrogen is released from the plasma, forming blisters that clog blood vessels. Blood circulation is disturbed mainly in the small blood vessels that supply the brain and muscles. May cause loss of consciousness, muscle cramps. By placing the victim in a baroque chamber and increasing the air pressure in it, the nitrogen in the blood dissolves again and the imminent symptoms disappear. The pressure in the chamber is then gradually reduced. This principle of treatment is still used today. Decompression sickness is more common in amateurs who do underwater sports and do not follow the set take-off speed.

#### Hyperbaric oxygenation

Modern hyperbaric medicine dates back only to the 20th century. In the middle when oxygen was used instead of air in baroque chambers. The founder of modern hyperbaric medicine is the Dutch doctor Ite Boerema. In the 1950s, he experimented with animals using baroque chambers using oxygen. I. Boerema used the already known law on the solubility of gas in water. In 1803, the English chemist William Henry, studying the absorption of gases in water, formulated a relationship that determined that the solubility of a gas in water is directly proportional to its pressure (Henry's law). Drawing No.1.



Drawing No.1. Henry's law. In the first container, the number of gas particles entering the liquid is negligible. By increasing the pressure of the gas in the second vessel, its penetration into the liquid is significantly higher.

I. Borem's most important experiment was performed in a baroque chamber filled with oxygen, then its pressure was raised to 3 atmospheres. A piglet was placed in the cell. Under these conditions, the animal's whole blood was replaced with saline. The piglet continued to live without blood, but only in this environment. 1956 Boerem published an article in the scientific journal "Life without blood", in which he described the experiment and gave reasons for it. According to the laws of physics, under higher pressure conditions, the solubility of oxygen in a liquid increases rapidly, and it becomes an oxygen-supplying tissue, in addition, in sufficient quantities to sustain life even in the absence of hemoglobin. In the following years, extensive clinical trials were conducted in medicine and from the 20th century. second-party hyperbaric oxygenation (HBO) became a recognized and effective method for the treatment of many diseases and pathologies. Clinical experience has confirmed the usefulness of the method, and experts have identified pathologies for which HBO is the method of choice and can save lives. In addition, there are a number of diseases that can be significantly treated with HBO, and experts give recommendations and recommendations for its use. Single or multi-bed barcodes are used for treatment. A single baroque chamber is a cylinder that places a patient in an oxygen environment under elevated pressure. Figure No.2. Multi-chamber cells accommodate several patients, fill them with air and allow them to breathe oxygen through a special mask. When the patient is placed in the baroque chamber, it is hermetically sealed and gradually filled with oxygen to the selected pressure. The pressure in the chamber rises gradually and during this time the feeling is similar to taking off an airplane. The ears are the most sensitive organ that responds to changes in pressure. To reduce the unpleasant feeling, swallow movements should be made, use chewing gum. When the required pressure is reached in the chamber, the discomfort disappears. The patient is lying in the chamber. The camera wall is equipped with portholes, which allows medical staff to monitor the progress of the session. You can also communicate through the camera's built-in phone. Baroque chambers are located in special rooms, where all safety regulations are observed, because the chambers use high pressure and a high concentration of oxygen. Figure No.3.



Figure No.2. Hyperbaric oxygenation chamber. Figure No.3. Barozale

The duration of the session is usually 45-60 minutes. As the session takes place in an oxygen environment, safety rules must be observed. No items should be brought into the cell, the suit should be made of cotton, and grounding should be done carefully. Prior to the session, there should be a doctor's examination, and each patient's medical staff will be instructed and interviewed. During an HBO session, all tissues in the body become saturated with oxygen. Blood plasma becomes the oxygen carrier. This allows oxygen to be delivered to all tissues, including where erythrocytes carry access. This is in places where blood vessels have narrowed due to inflammation, swelling or other reasons, where blood supply and oxygen supply are impaired. Of course, such a high oxygen saturation can be achieved only during the session, so a more lasting effect can be achieved only by repeated sessions. This is similar to all physical therapy methods.

#### Treatment of life-threatening pathologies

As a saving and extreme method, HBO therapy is performed in cases of carbon monoxide poisoning. The cause is careless handling of heating stoves. Many toxic gases are released in the event of fire and often poison people involved in rescue operations. Flu gas is considered a poison of hemoglobin, it binds very closely and for a long time to hemoglobin. The latter loses the ability to attract and transfer oxygen molecules. The body develops severe oxygen starvation or hypoxia. In a high concentration of carbon monoxide, a person dies within a few minutes. Hemoglobin can only be released from carbon monoxide in a high oxygen environment. In these cases, urgent inhalation of pure oxygen is required, but the most effective is oxygen respiration under the pressures provided by HBO therapy. When breathing atmospheric air, hemoglobin is released from carbon monoxide within 5 hours, in a pure oxygen (100%) environment - within 1.5 hours, but in an oxygen environment in a baroque chamber within 20 minutes. It should be noted that only timely initiation of therapy is successful. In the later period of poisoning, HBO therapy only helps to mitigate the effects. Carbon monoxide poisoning has been identified as an absolute indication for HBO therapy. Such indications are also present in decompression sickness (mentioned above) and in patients with a relatively rare but dangerous wound infection, gas gangrene. This pathology is caused by special microbes (anaerobes), which infect large, dirty wounds with severe bleeding disorders. These microbes die rapidly in the oxygen environment, so HBO therapy provides significant improvement

and should be performed as soon as possible. These pathologies endanger the patient's life and are treated in hospitals.

HBO in outpatient practice. Extensive use of HBO is possible in outpatient practice. The list of diseases for which this method is used is very long. This may include all pathologies that interfere with the oxygen supply. They are common in almost all diseases. The main task is to detect and eliminate the cause of the disease. HBO therapy in these cases is only helpful in reducing the hypoxia caused by the disease and preventing damage. By preventing oxygen starvation, the body's tissues retain their ability to regenerate. This means that the healing process is promoted. This is especially important in cases of chronic diseases, when the body's defenses are weakened. HBO therapy may seem to help and be used to treat all diseases. However, the mechanisms of disease are much more complex and we have not understood everyone. HBO therapy should be used in pathological cases when it is based on clinical evidence of its efficacy and safety.

### **Indications**

Practice has shown that HBO benefits in the following pathologies:

Purulent and non-healing wounds (diabetic foot, trophic ulcers)

Infected wounds with the presence of anaerobic microbes and necrotic (dead) tissue

Compression syndrome (extensive traumatic soft tissue damage with severe edema)

Auditory neuritis, sudden deafness

Scleroderma (connective tissue disease)

Osteomyelitis (a bone infection with purulence)

Rehabilitation period after cerebrovascular disorders

According to Pauls Stradiņš Clinical University Hospital, the experience can be improved in the treatment of other pathologies and conditions. Our observations suggest that HBO can be used in patients with multiple sclerosis, psoriasis, peripheral vascular pathology, Meniere's syndrome, in the post-fasting period, in athletes after overload, in situations after mental and physical overload. There have been some observations of improvement in children with autism. We have obtained the best results in the treatment of patients with complications of diabetes and hearing impairment. Then a little more about them.

### **Assistant for the treatment of diabetic ulcers**

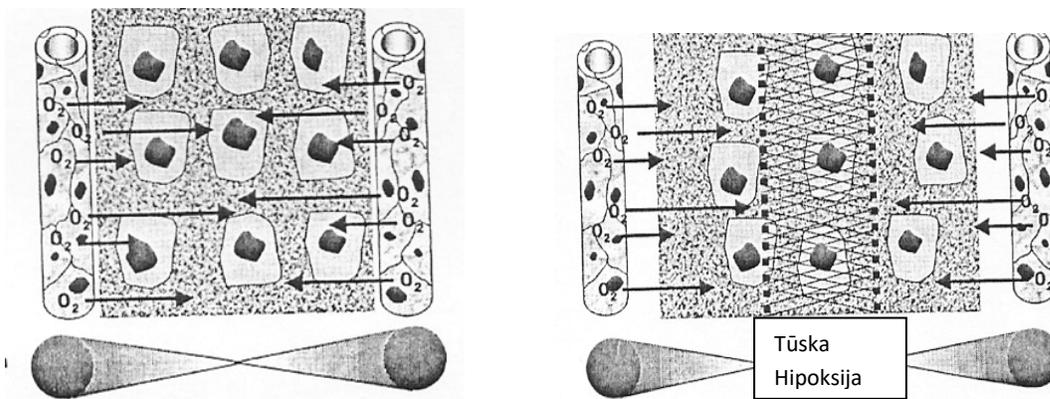
Diabetic foot ulcer is one of the most common complications of diabetes. It is an ulcer caused by a tissue metabolism disorder. Even from a very minor injury, an incurable ulcer develops, which is superficial and small at first, but then expands more and more. Diabetic foot ulcers are characterized by tissue ulceration and infection caused by diabetic neurological changes and vascular disease in the legs. Metabolic disorders caused by diabetes quickly affect the nervous system. Such changes are termed diabetic neuropathy. Up to 50% of patients with type 2 diabetes have diabetic neuropathy. The most common symptoms of neuropathy are in patients with 25 years of diabetes. Diabetic neuropathy is more common in patients over 40 years of age with poorly controlled glycemia, high blood fat, high blood pressure and weight gain. Diabetic foot is formed by a combination of poor blood circulation and neuropathy. Diabetic neuropathy can cause numbness or inability to feel pain, heat and cold. Diabetic patients with neuropathy may develop small wounds, blisters, bedsores that the patient does not feel. If these minor injuries are not treated, ulcers can develop. They often become infected and increase in size. Extensive infected ulcers become incurable and can endanger the patient's life. Ulcers are difficult to treat, they are painful, and the

dying tissue causes a rash with an unpleasant odor. Therapy is very complicated - it is a long, laborious, expensive and difficult journey. Neuropathies are the most common complications of diabetes with a high risk of morbidity. About 25 percent of diabetic patients have neuropathic complaints. Due to peripheral neuropathy, 50 to 70 percent of non-traumatic leg amputations are performed. The risk of leg amputation in diabetic patients is 25 times higher than in non-diabetic people. 40-70% of all leg amputations are related to diabetes. 85% of amputations are caused by a foot ulcer. In order to prevent and delay the development of diabetic peripheral neuropathy, it is very important to achieve good and stable compensation for diabetes, blood glucose levels that meet the goal recommended by the doctor. Studies show that it helps reduce the prevalence of diabetic peripheral neuropathy by up to 40%.

The second cause of ulcer development is diabetic peripheral vascular disease, which reduces the supply of oxygen to the tissues. The arteries narrow, resulting in a significant reduction in blood flow to the lower legs and feet. Poor blood circulation contributes to diabetic foot problems by reducing the supply of oxygen and nutrients to the skin and other tissues, so wounds heal poorly. Poor blood circulation in the ulcer area is the cause of poor wound healing, poor tissue protection against infection. Ulcer healing is also hindered by inflammation. Prevention of foot problems in diabetics is especially important, because poor blood circulation hinders healing processes, promotes the addition of infection. In most cases, amputation is necessary because of a combination of deep infection and ischemia. Patients with atherosclerotic stenosis of the peripheral arteries have a significantly higher incidence of five years of amputation.

According to the literature, the most common indication for leg amputation is gangrene, widespread infection and persistent ulcer.

Given the many factors that determine the onset of ulcers, healing disorders, and the addition of complications, optimal treatment of diabetic ulcers requires active ulcer treatment tactics. It is important to ensure timely cleansing of dead tissue, elimination of infection, regular assessment of the condition and size of the ulcer. One of the main factors needed to heal an ulcer is the supply of oxygen. Oxygen is especially needed for the formation of new tissue at the site of damage, oxygen is used extensively by blood cells to kill germs. It is in the area of chronic ulcers that the amount of oxygen is reduced. This is due to vasoconstriction caused by diabetes, chronic inflammatory tissue edema, increased connective tissue and scar tissue formation in hypoxic conditions. Regeneration of normal tissues and blood vessels can only take place under conditions of sufficient oxygen. Many studies have been performed to determine the partial pressure of oxygen in the tissue in the area of non-healing ulcer. It has been shown that if this pressure in the surrounding tissue of the ulcer is less than 30 mmHg, the healing process does not take place. When pure oxygen is given to breathe, its content in the bloodstream increases significantly, but oxygen does not enter the wound area where there is a poor blood supply. In this situation, the supply of oxygen at elevated atmospheric pressure, which can be ensured by the hyperbaric oxygenation method, is crucial. Under normal conditions, by enriching the inhaled air with oxygen up to 100%, it is only possible to completely saturate it with hemoglobin. Hypoxia is not prevented in poorly bled tissues. Other oxygen transfer pathways are involved in the HBO method. As the partial pressure of oxygen in the respirable gas mixture increases above one atmosphere, its capacity in plasma, lymph and tissue fluid increases, leading to an increase in the supply of oxygen to the tissues. Under these conditions, oxygen can be transferred to tissue fluid and lymph. Oxygen enters the wound tissue with a poor blood supply. The oxygen pressure here reaches more than 100 mmHg, which is sufficient for a normal wound healing process. Drawing No.2.



Drawing No.2. Oxygen diffusion in normal tissues and edema

By receiving more oxygen, the wound is better able to cleanse, leukocyte function is improved, and tissue and blood vessel regeneration is promoted. Of course, such therapy will only help if diabetes is treated properly, and surgical treatment of the ulcer is performed properly and thoroughly. Such combination therapy can be performed in both hospital and outpatient settings. The course of treatment usually consists of 7-10 sessions. Session duration 60 minutes. In some cases, the doctor will prescribe longer sessions or more sessions. Impressions take place daily or every other day. The duration and mode of the session can be adjusted to the patient's well-being.

### Hearing impairment

Hearing loss can occur for a variety of reasons, depending on which part of the ear is damaged. Most often, hearing is impaired or lost due to changes in the function of the inner ear. Disorders can be in the inner ear (snail) or in the nerve pathways from the inner ear to the brain. This pathology is referred to as sensory hearing loss. It is caused by sudden loud noise, ototoxic drugs, head injuries. Hearing loss occurs suddenly. When a person wakes up in the morning, he does not hear with one ear, or observes it when talking on the phone. Occasionally accompanied by ringing in the ears or dizziness. It should be noted that the inner ear can be damaged in two ways - either acute or slow progressive. **Acute damage to the inner ear (acute sensory neural hearing loss) requires prompt treatment.** After 4-5 days, hearing loss may be irreversible. An ear doctor should be consulted and medical therapy instituted. It is prescribed drugs that reduce inflammation, improve blood circulation in the inner ear. In these situations, it is important to start HBO therapy immediately, as it can reduce the swelling caused by inflammation, is able to supply oxygen to the nerve cells in the inner ear through the lymph and compensates for the lack of oxygen. Extensive research on the use of HBO in the treatment of sensory hearing loss has been conducted in Italy, Germany and Japan. The results showed that the timely addition of HBO to the course of treatment gave significantly better results in hearing restoration. Based on extensive clinical experience and positive results, the European Society of Ear and Neck Physicians published guidelines for the treatment of sensory hearing loss in 2019, which recommended that it be combined with HBO during the first 2 weeks of initiating drug therapy.

### Sound trauma or acute trauma

Acutrauma is a specific damage to the inner ear. It is caused by short-term loud sounds or prolonged noise; noise with a sound frequency above 2000 Hz is particularly harmful. In more severe cases, hearing is impaired and general symptoms are added: headache, tiredness, sleep disturbances, changes in heart rate and blood pressure. The peculiarity of the inner ear circulation is that it is

provided by only one relatively thin blood vessel from the cerebral artery. Loud sound can cause vascular spasm in the inner ear and subsequent oxygen starvation or hypoxia. In contrast, lymph circulation in the inner ear structures is abundant. HBO therapy, by providing good oxygen solubility in the lymph, is able to prevent hypoxia. According to the German otolaryngologists Pilgramm and Schumann, HBO therapy is the most effective method of treating acute trauma. In 2005, Japanese doctor Okamoto proved that HBO therapy should be given within the first 10 days after an injury. Summarizing the many years of experience, it is safe to say that the inclusion of HBO in the complex treatment of many diseases has proven to be a useful or even necessary component. The method is safe, the number of complications is small, they are very rare.