

THE USE OF PHYSICAL MEDICINE WITH PARTICULAR USE OF HYPERBARIC OXYGENATION IN THE TREATMENT OF ATHEROSCLEROSIS

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ABSTRACT

Introduction: The possibilities of physiotherapy in treating complications of atherosclerosis are extremely broad, especially regarding physical therapy modalities. However, increasingly recent studies demonstrate the remarkable effectiveness of the Laserobaría 2.0_S device, which combines all essential physical methods: ozone therapy, oxygen therapy, phototherapy, and magnetic field therapy. Pharmacological treatment and prevention of arterial diseases through kinesiotherapeutic exercises and an appropriate diet are also of great importance.

Methods: The work includes an in-depth literature search in PubMed and Google Scholar, covering published articles.

Results: The review demonstrates the significant role of physical therapy in the treatment of atherosclerosis complications, highlighting in particular the Laserobaría 2.0_S device as an effective method using all essential physical factors in the treatment of hard-to-heal wounds caused by lower-limb atherosclerosis.

Conclusions: This review confirms the essential role of physiotherapy in treating complications of atherosclerosis. It shows that the use of physical methods in the treatment of ulcers is necessary and confirms the effectiveness of the Laserobaría 2.0_S device. The literature review supports the benefits of kinesiotherapy and a healthy diet in preventing the development of atherosclerosis.

Keywords: Atherosclerosis, physiotherapy, oxygen therapy, hyperbaric therapy, Laserobaría, prevention.

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ATHEROSCLEROSIS AS A CIVILIZATION DISEASE

Atherosclerosis is a chronic, civilization-related inflammatory disease of arterial vessels that develops over a period of several or even dozens of years, often without symptoms. The effects usually become apparent only during serious cardiovascular incidents. The essence of atherosclerosis is the gradual narrowing and stiffening of blood vessels. The etiology of this process lies in the deposition of cholesterol in the arterial walls, which leads to the formation of advanced atherosclerotic lesions known as plaques. As the disease progresses, cholesterol deposits accumulate in various arteries—most commonly in lower-limb vessels and coronary arteries. These deposits primarily accumulate in the arteries of the lower extremities and the coronary arteries. Unfortunately, the rupture of an atherosclerotic plaque leads to the formation of a blood clot, the effects of which can often be life-threatening, leading to heart attacks and strokes. In fact, atherosclerotic disease may begin developing as early as childhood, with symptoms typically appearing after the age of 50 [1].

A major concern in modern medicine is not only strokes or myocardial infarctions as complications of atherosclerosis, but also chronic wounds—particularly of the lower limbs—resulting from vascular diseases. Chronic wounds, particularly in the lower limbs, are an increasingly difficult-to-treat consequence of venous and arterial disease. Wounds resulting from atherosclerosis complications often lead to amputation. Limb ablation undoubtedly reduces the patient's quality of life. Methods that effectively treat non-healing lower limb wounds are constantly being sought [2].

PHYSIOTHERAPEUTIC METHODS IN ATHEROSCLEROSIS AND ITS COMPLICATIONS

OZONE THERAPY

Ozone therapy is employed in the treatment of chronic non-healing wounds and skin infections. Ozone is used in bacterial and fungal infections, skin diseases, and inflammatory conditions, making it an effective method with antibacterial, antifungal, and anti-inflammatory properties. Ozone stimulates the release of proteins responsible for cell growth and replication involved in immune response. Additionally, it supports the formation and diversification of blood morphotic elements and influences immune system functioning [3,4].

Ozone has a significant effect on ATP—it increases the amount of oxygen and ATP released into tissues, which results in increased oxygen levels in those tissues. Additionally, ozone supplies tissues with nutrients, supporting wound healing and regenerative processes. Ozone influences the oxidation of N-acetylglycosamine, which has the ability to support cellular regeneration and renewal. Oxidation of this compound (N-acetylglycosamine) blocks the receptor responsible for virus-cell contact and prevents virus penetration into tissues. This demonstrates ozone's effective antiviral properties [5]. Ozone inhibits certain acute-phase proteins, thereby blocking inflammation occurring in the body [6,7].

Ozone is considered one of the most effective oxidants with disinfecting and antiseptic properties. It is widely used for neutralizing bacteria and microorganisms [8], and its bactericidal activity is about 50× stronger than chlorine. When delivered to tissues, ozone rapidly destroys bacterial cells, and short exposure prevents the development of drug-resistant strains [9,10].

However, ozone used in gaseous form may cause headaches and dizziness. The most serious side effects include neurological disturbances. Ozone is also harmful to the respiratory system, causing the accumulation of toxic products (free radicals, peroxides) that may damage alveolar walls or lead to irreversible changes in ciliated lung cells, potentially causing fibrosis. These effects may lead to dyspnea or asthma attacks [11,12].

Therefore, the safest form of ozone administration is topical application. This form of ozone does not have a toxic effect on cells. They are not destroyed by contact with active oxygen thanks to their natural defense mechanisms. These mechanisms include antioxidant systems that inhibit the harmful effects of oxygen [13].

Ozone therapy is a safe and effective treatment method when applied in accordance with medical guidelines and at appropriate concentrations. The use of ozone can induce numerous beneficial biological responses in the human body, including the restoration of homeostatic balance within the internal environment. This indicates that ozone administration enables optimal physiological functioning despite changing external conditions. A deeper understanding of ozone's properties may contribute to its broader application in both human and veterinary medicine. Comprehending the underlying positive effects of ozone on the organism may also lead to remarkable therapeutic outcomes in cases where conventional treatment methods prove ineffective [14].

Ozone therapy produces a biosynthetic effect—activating the protein synthesis sequence, increasing the number of ribosomes in proteins and mitochondria in cells. This mechanism explains the increased regenerative potential of tissues and organs. The most important benefits of ozone in wound healing include: anti-inflammatory properties, improved regional circulation, stimulation of regenerative processes, hemostasis in capillary bleeding (stopping bleeding), and painless treatment [15,16].

PHOTOTHERAPY

Light therapy finds application in various fields of medicine, including dermatology, neurology, and rehabilitation. Its especially important use is in the treatment of hard-to-heal wounds caused by atherosclerosis [17,18].

Infrared light increases nitric oxide, which leads to vasodilation and an analgesic effect. Infrared light reduces muscle tension and increases the pain threshold. This last effect is crucial in wound healing, as the patient's lack of real pain perception often leads to uncontrolled tissue damage, which in turn increases ulceration and infection in these wounds [19].

Ultraviolet light provides analgesic effects and antimicrobial, antibiofilm properties. Wound-healing difficulties are often caused by biofilm formed by microorganisms, which is highly tolerant to environmental conditions and therefore difficult to treat [19]. UV light does not produce heat but has strong

biological effects, improving metabolism, accelerating bone mineralization, stimulating endocrine glands, improving oxygen metabolism, lowering blood pressure, and supporting the hematopoietic system [20,21].

Polarized light is undoubtedly safe for patients with epilepsy because it does not emit heat. It has anti-inflammatory and analgesic effects. Most importantly, it supports tissue regeneration and improves circulation by accelerating granulation [22,23].

MAGNETIC FIELD THERAPY

Magnetic field therapy improves microcirculation and peripheral blood flow, making it effective in treating complications of atherosclerosis. It promotes capillary formation, stimulates cell growth and nutrition, and supports tissue regeneration, fracture healing, and provides anti-edematous, anti-inflammatory, and analgesic effects. Treatments typically consist of a series of several 10-minute sessions [24].

The actions of alternating magnetic fields result from three main biophysical effects:

- electrodynamic effects on ionic currents,
- ionic cyclotron resonance of cations and anions in bodily fluids,
- magnetomechanical effects of the magnetic field on particles with uncompensated magnetic spins [25].

Magnetotherapy reduces the need for non-steroidal anti-inflammatory drugs and improves quality of life. It is a non-invasive method used both in medicine and rehabilitation. Magnetic field therapy is contactless, painless, and safe, making it particularly suitable for treating and preventing many conditions, including ulcerating wounds. Analgesic effects persist even after exposure ends [26].

DEVICES USING PHYSICAL FACTORS

HYPERBARIC OXYGEN THERAPY

In sports medicine, hyperbaric oxygen therapy (HBOT) is sometimes used as "legal doping." It supports regeneration not only in athletes but also in patients with venous and arterial diseases. Hyperbaric therapy significantly aids regenerative processes in damaged tissues. It has been shown to positively influence the regeneration of bone tissue, skeletal muscles, and metabolism [27,28].

Hyperbaric oxygen therapy enhances the effects of antibiotics, minimizes the production of bacterial toxins, and disrupts the growth of Gram-positive and Gram-negative bacteria. Increasing the partial pressure of oxygen in tissues improves blood flow in hypoxic tissues. Oxygen therapy also reduces swelling in burnt tissues, improving blood allocation to these areas. Research also confirms the effectiveness of hyperbaric oxygen therapy in sepsis – oxygen used stimulates the immune system. Oxygen therapy has antibacterial effects, but it should be remembered that oxygen is primarily effective against anaerobic bacteria [29,30].

During healing, oxygen demand increases, while chronic tissue hypoxia impairs healing [31]. HBOT uses increased pressure and pure oxygen inhaled by the patient inside the chamber. Oxygen is transported by blood and plasma throughout the body, improving

oxygenation of tissues and organs—crucial when tissues are damaged and circulation is impaired. Oxygen therapy accelerates regeneration and reduces edema by causing vasoconstriction [32].

Unfortunately, due to the high toxicity of the oxygen inhaled during the procedure, hyperbaric oxygen therapy is not a completely safe treatment method. Oxygen molecules in the body are converted into water, which creates toxic intermediate metabolites. Crucially, it is mostly older people who suffer from atherosclerosis of the lower limbs, and age plays a significant role in hyperbaric oxygen therapy. Adverse changes occur more easily and quickly in older people. A disturbed balance between active oxygen species and antioxidants triggers a cycle of unfavorable changes. This process damages the structure of nucleic acids and cell membranes [33,34].

The lungs may seem most vulnerable to oxygen toxicity, but brain tissue is the most sensitive. Symptoms of oxygen toxicity include chest tightness and pain, cough, irritation of the trachea and bronchi, apnea, reduced lung capacity, nausea, dizziness, hiccups, tremors of the eyelids and face, vision and hearing disturbances, hallucinations, and cataracts. More serious complications include damage to the alveolar epithelium and capillary endothelium, resulting in pulmonary edema and hypoxia [35,36].

NORMOBARIC THERAPY

Normobaric therapy is oxygen therapy in normobaric chambers, involving breathing oxygen under slightly increased pressure and with elevated carbon dioxide [37].

Both normobaric and hyperbaric stimulate stem cell production, making them powerful regenerative therapies. Oxygen in this form supports immune response and improves overall organism resistance by revitalizing cells through tissue oxygenation and nutrient delivery. The difference lies in the presence of increased CO₂ in normobaric chambers, which improves oxygen transport from blood to cells. The combination of elevated pressure and increased CO₂ slows cell division, preventing premature aging. Normobaric has strong anti-inflammatory effects and stimulates cytoprotective compounds that enhance mucosal protection and create a physical barrier over ulcers [38].

However, as with hyperbaric oxygen therapy, attention should be paid to the risks associated with using a normobaric chamber. The health consequences of normobaric therapy include, above all, increased production of reactive oxygen species and free radicals. This is due to the greater availability of oxygen than in the atmosphere [39].

Hyperbaric oxygenation and hyperoxia are undoubtedly harmful to cells, including DNA. Damage to these cells can lead to the development of cardiovascular diseases, respiratory diseases, and even certain eye conditions, or increase the risk of a healthy cell transforming into a malignant tumor (due to mutation) [40]. Furthermore, literature describing normobaric therapy also mentions the presence of small amounts of hydrogen in the breathing mixture. While the presence of hydrogen gas promotes more effective tissue oxygenation and inhibits the destructive effects of free radicals that damage cellular structures [41], the literature also notes that this gas has no direct physiological impact on the human body under normobaric conditions, adding it to

the mixture compromises safety as it is a highly explosive and flammable gas [42].

LASEROBARIA 2.0_S

Laserobaria 2.0_S is a breakthrough in ulcer treatment because, unlike the devices described above (hyperbaric oxygen therapy and normobaria), it allows for the arrangement of treatments as a combined therapy. This means the treated area is simultaneously exposed to:

- hyperbaric oxygen therapy
- ozone therapy
- alternating magnetic field therapy
- low-energy red and ultraviolet light therapy [43].



Fig. 1 Fig. 1 Laserobaria 2.0_S Device. Source: Own material.

Tab. 1

Comparison of the Application of Physical Modalities in Devices: Hyperbaric, Normobaric, and Laserobaria. Source: Own material.

Physical factors	Hyperbaric therapy	Normobaric therapy	Laserobaric therapy
Ozone	-	-	+
Oxygen	+	+	+
Red light	-	-	+
Ultraviolet light	-	-	+
Magnetic field	-	-	+

The simultaneous use of the aforementioned physical modalities produces a strong synergistic effect, intensifying key regenerative mechanisms responsible for the transformation of glandular epithelium into squamous epithelium, thereby facilitating the repair of pathologically altered tissues. Moreover, Laserobaria enhances tissue nourishment, oxygenation, and perfusion, while maintaining an antiseptic environment within the wound. This contributes to significant acceleration and improvement in the dynamics of chronic wound healing [44].

An important consideration is that Laserobaria is a portable device designed for localized application. Consequently, it may be regarded as a safe treatment option, as it does not entail systemic side effects such as respiratory, neurological, or visual disturbances—complications that may arise during systemic hyperbaric or normobaric therapies [45].

Studies on the effectiveness of laser barium therapy in the treatment of leg ulcers have demonstrated a cyclical decrease in the severity of the inflammatory reaction in the tissues surrounding the wound. Furthermore, during treatment, the severe pain reported by the patient gradually subsides, and in subsequent phases, completely subsides. The treatment factors are selected individually for each patient. The treatment cycle lasts 10 days, and a single session lasts 30 minutes to 1.5 hours [46].

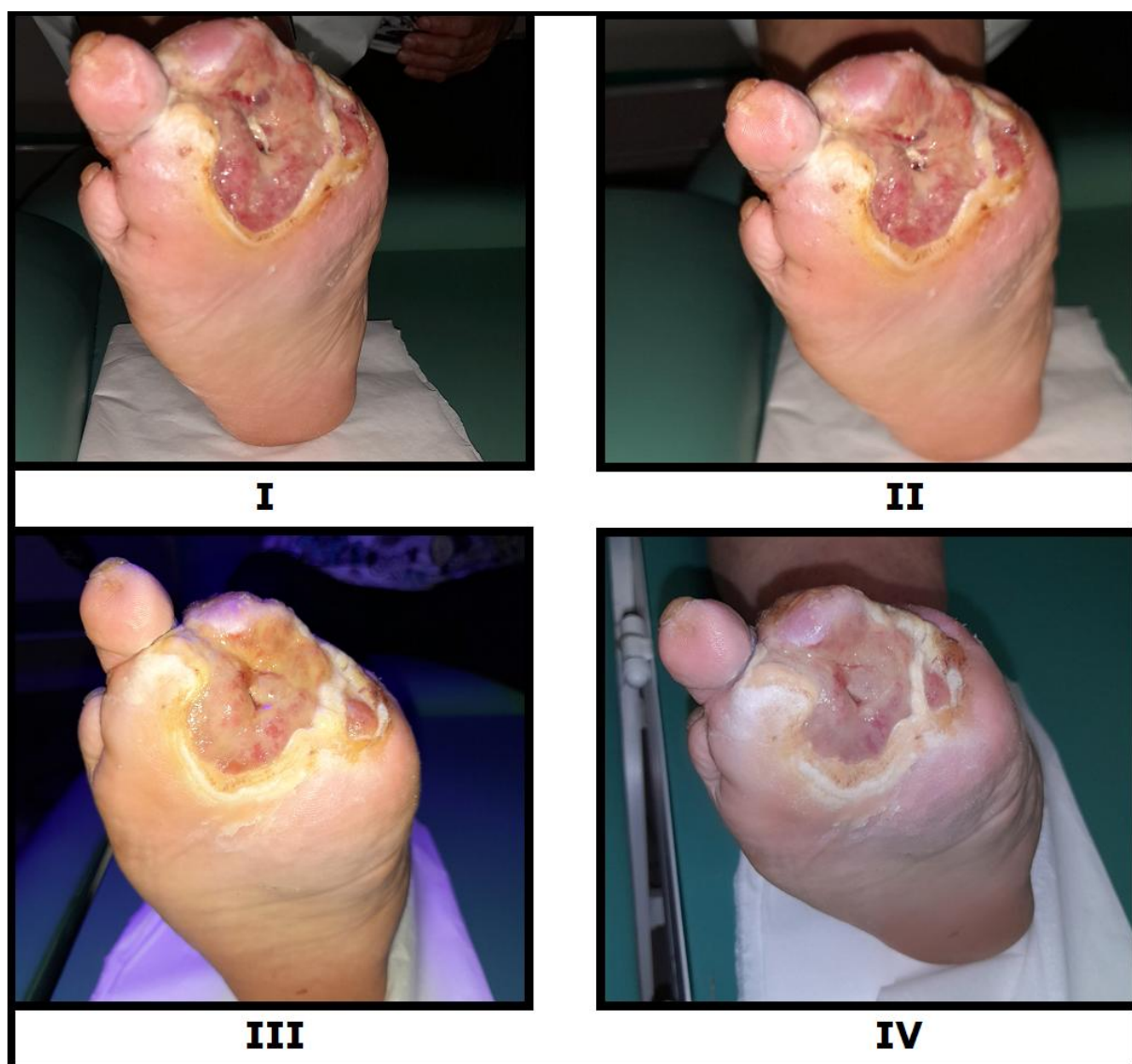


Fig. 2 Ulcer Treated with the Laserobaria 2.0.S Device. 10-Day Therapy. Each Session Lasting 1.5 Hours
 I – Wound before treatment; II – Wound after the 5th session; III – Wound after the 10th session; IV – Wound 2 weeks after completing the 10-day therapy.
 Source: Own material.

KINESIOTHERAPEUTIC EXERCISES

A key component in both the treatment and prevention of atherosclerosis is kinesiotherapy, i.e., therapy through movement. Kinesiotherapy includes all forms of physical activity, including walking training [47].

Walking training is one of the most important conservative treatment methods for ischemic changes in the lower limbs. According to TASC II recommendations, supervised treadmill walking should constitute a fundamental component of management in all patients presenting with intermittent claudication [48].

Supervised walking training should form an essential part of therapy in all individuals with atherosclerosis and symptoms of intermittent claudication. It must be emphasized that intense pain in the lower limb muscles should be strictly avoided during exercise. Walking to the point of maximal pain leads to

adverse outcomes and increases the risk of cardiovascular complications [49].

Physiotherapy for patients with atherosclerosis, including those with intermittent claudication, may also incorporate resistance exercises, isotonic exercises, and targeted workouts for specific muscle groups of the lower limb, including the triceps surae, tibialis anterior, quadriceps, knee flexors, and gluteal muscles [50].

A sedentary lifestyle without regular physical activity exposes individuals to two major risk factors for coronary artery disease: diabetes and hypertension. Therefore, kinesiotherapy plays a crucial role in the prevention, treatment, and reduction of complications related to atherosclerosis [51].

PHARMACOLOGICAL TREATMENT

A discussion of pharmacological treatment for atherosclerosis is crucial. In addition to physical therapy, pharmacological treatment is crucial, as it is the cornerstone of atherosclerotic disease therapy. Pharmacotherapy aims not only to improve patients' quality of life by alleviating symptoms but also to prevent heart attacks, strokes, and premature death. Pharmacotherapy is based on the use of several groups of drugs with different mechanisms of action [52].

Pharmacotherapy for atherosclerosis includes, among others: statins that lower LDL cholesterol, lipid-lowering drugs, antiplatelet and anticoagulant agents, and medications that lower blood pressure. The selection of medications should take into account individual risk factors, comorbidities, and possible contraindications [53].

DIET AND PREVENTION

There is a well-established correlation between the occurrence of cardiovascular diseases linked to atherosclerosis and dietary composition. Proper nutrition forms the basis of prevention and the reduction of clinical complications of atherosclerosis. A well-designed diet helps normalize lipid levels, blood pressure, and fibrinogen concentration. Maintaining a balance between energy intake and expenditure also prevents overweight, obesity, and type 2 diabetes—factors that significantly increase the risk of atherosclerosis [54].

Foods rich in saturated fatty acids, dietary cholesterol, and trans fats should be replaced with products providing essential unsaturated fatty acids, particularly omega-3 and omega-6.

A rational dietary approach is essential for preventing atherosclerosis. The main objective is to maintain low serum cholesterol levels, particularly LDL cholesterol, to reduce the risk of heart and arterial diseases. As previously noted, the diet should include unsaturated fatty acids as well as high-fiber foods,

antioxidant vitamins, fruits, vegetables, and low-fat products [55].

An increasing body of evidence highlights the benefits of margarine enriched with stanols (compounds synthesized from plant sterols naturally present in fruits, nuts, grains, and vegetable oils). Studies show that stanols reduce total cholesterol and LDL levels in individuals with both normal and elevated cholesterol levels. Current literature reports that stanols reduce total cholesterol by approximately 10% and LDL cholesterol by around 15% or more. British researchers have demonstrated a significant reduction in LDL levels after only one month of stanol and sterol supplementation [56,57].

CONCLUSIONS

Atherosclerosis of the lower-limb arteries is a systemic disease, and atherosclerotic lesions located in these arteries constitute a serious risk of limb loss due to ischemia. Once a patient develops atherosclerosis and its complications include chronic, non-healing wounds of the lower limbs, appropriate physiotherapeutic management becomes essential.

In the treatment of wounds, modern medicine utilizes various physical modalities such as ozone, oxygen, red light, ultraviolet light, and magnetic fields. These methods are typically applied separately. Devices such as hyperbaric oxygen chambers or normobaric systems promote tissue regeneration through the application of high pressure and pure oxygen, yet they rely on only one of the aforementioned factors. Therefore, a breakthrough in wound management is the Laserobaria 2.0_S system, which integrates multiple approaches: ozone therapy, oxygen therapy, phototherapy, and magnetic field therapy.

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