# RESPIRATORY GYMNASTICS IN HYPERBARIC OXYGEN THERAPY

Miroslav ČERNICKÝ* – Eva KRÁLOVÁ – Dominika JANČOVÁ –
Zdenka KRAJČOVIČOVÁ – Vladimír MELUŠ – Jana SLOBODNÍKOVÁ

*Faculty of Healthcare, Alexander Dubček University of Trenčín, Študentská 2, 911 50 Trenčín, Slovak Republic*
* Corresponding author E-mail address: miroslav.cernicky@tnuni.sk

**Abstract**
*Objective:* The article deals with the impact of respiratory gymnastics on the curve of exhaled oxygen ($ExO_2$) from the monitoring system consisting of pressure depending on $ExO_2$ in the units of mmHg from the duration of exposure in patients treated by hyperbaric oxygen therapy. Sub-objectives were focused on re-education of breathing and further depended on individual circumstances of the selected patients and concerning reduction of spasticity, increase of muscle strength and the extent of motion.
*The survey sample:* Three respondents aged from 31 to 85. Two patients with Dg. Stroke and one patient with Dg. Sudden hearing loss. All the respondents were assigned to the treatment with hyperbaric oxygen therapy at the Centre for Hyperbaric Oxygen Therapy, Faculty of Healthcare of Alexander Dubcek University of Trencin in Trencin.
*Methods:* Qualitative research: In the three case studies we have focused on monitoring of exhaled $O_2$ recording system Haux-MEDICAL MONITORING SYSTEM, in 12-seat hyperbaric chamber Haux-STARMED 2200. The record of $ExO_2$ consisted from the dependence of $ExO_2$ pressure in the units of mmHg during the exposure.
*Results:* The changes in dynamics of breathing curves were objectified in the first and third patient and expressed as a percentage. In the first patient, the dynamics of the curve $ExO_2$ changed after 20 exposures and 10-exercise units with localized breathing 6.8% without noise variance at $ExO_2$ increase of 81 mmHg. In the third patient the changes were obtained after 6-exposures and 5-training units with localized breathing the dynamics curve $ExO_2$ was changed by 10.2% with the significant reduction in the amount of noise compared with noise during the second exposure. $ExO_2$ value raised in 122 mmHg. In patients with tinnitus (Case Study No. 2) there was the value $ExO_2$ and low noise from the beginning of therapy, as was evidenced in the curve $ExO_2$. The level of noise exposure in the last phase was reduced which is evident in the curves $ExO_2$ in the second case study
*Conclusion:* In the various indications of hyperbaric oxygen therapy, the main objective of respiratory gymnastics for patients treated in it is always the same: to achieve increase in the levels of medical oxygen in blood, and thus increase its amount in the body after exposure.

**Key words:** Hyperbaric oxygen therapy, Respiratory gymnastics, Re-education of breathing

## Introduction

Respiratory gymnastics represents the essential part of the rehabilitation programme in movement therapy of patients. By localized breathing lung ventilation is maintained, while breathing deepens, then there is an exchange of oxygen and carbon dioxide in the alveoli that were not previously ventilated. The exercise thus enables patients to inhale larger amount of oxygen and it has a significant impact on the therapy itself during hyperbaric oxygen therapy (HBOT). During HBOT patient inhales a 100% medical oxygen under the increased pressure, thereby, in accordance with increased pressure there is reached higher concentration of oxygen in a patient compared to the inhaled air under the conditions of atmospheric pressure.

## Hyperbaric Oxygen Therapy

HBOT is modern therapeutic method. A patient during the HBOT is subjected to 100% medical oxygen at the pressure higher than the atmospheric one, and is placed to a specially designed chamber. The consequence of HBOT is the increase of the oxygen concentration in blood. This happens as the result of Henry´s Law, according to which the degree of solubility of gas in body fluids is proportional to the partial pressure of the gas. Blood around the alveoli is increased in higher amount of oxygen as compared to the inhalation of atmospheric pressure which is caused by the impact of external pressure during HBOT. The more dissolved oxygen is in the blood, the better it gets to the organs and tissues, and thus penetrates deeper into ischemic areas, than under the conditions of normal pressure (101.325 kPa, 1 ATA). During the HBOT the oxygen is dissolved into body fluids – blood plasma, lymph and CSF. The main objection of the treatment is, except of others, to promote healing and regeneration of the cells and tissues in the body [1-3].

HBOT as adjunctive therapeutic method works in the indicated conditions by following: providing oxygen substitution, through physical effects it eliminates air bubbles, and finally it has an immunosuppressive effect. Some indications are documented in clinical studies in considerable detail, others are the subject of lesser studies. Indication spectrum for HBOT is relatively wide. In some diseases HBOT is the basis for life-saving treatment, in many of them it is an important complement to other treatment modalities HBOT [2,4].

HBOT is typically indicated for example in the treatment of decompression sickness, gas embolisms and poisoning caused by carbon monoxide. It is also effective in the treatment of gas gangrene, anaerobic infections, diabetic foot and Burger´s disease, atherosclerosis, Crohn´s disease, ulcerative colitis, atopic dermatitis, sudden idiopathic of hearing loss, then in chronic osteoarthritis and stroke, multiple sclerosis, burns or frostbite. Various studies describe also the positive effect of HBOT to convalesce after injury or recovery in the sports activities, which extends the use of HBOT in the field of physiotherapy [4,5].

During HBOT, the patient is placed in a hyperbaric chamber, either a single seat or multiple seat. Both a single-seat hyperbaric chamber and also multiple seat chamber (fig. 1) may involve breathing in a pressurized chamber where patients inhale a 100% medical oxygen through a mask; or a patient is directly placed in the atmosphere of a 100% medical oxygen. During the stay each patient in the chamber is monitored by health professionals. There is so called technical staff who is responsible for the safety in HBOT.


***Figure 1:*** *Multiple seat chamber of the Centre for hyperbaric oxygen therapy, Faculty of healthcare, ADU Trenčín*

Before entering the chamber, the patient is informed about the progress and method of treatment, desirable and undesirable effects of HBOT, about the steps and precautions that are inevitable to be observed during the treatment. A patient must report adverse events and all the changes in health condition. The duration of one exposure is approx. 90 minutes, the number of exposures prescribed by the doctor is indicated according to the diagnosis, from 10 to 20, in some cases even more. During the stay in a hyperbaric chamber, the patient should sit at the seat determined before. Above each seat there is available an emergency call button when necessary.

The standard exposure in HBOT has three phases: compression, isocompression and decompression. In the phase of compression the pressure in the chamber is increased. At low compression there will be increased the pressure to the desired level set depending on the patient´s diagnosis (e. g. in ENT diagnoses such as: Sudden hearing loss and Tinnitus and for Stroke (CVA) 2 ATA, in chronic wounds 2.5 ATA). The duration of compression phase and the increase in pressure and speed resulting from that depends on the patient´s ability to equalize pressure in the middle ear with the pressure in the chamber. To that helps the application of nasal decongestive, Valsalva maneuver (closing the nostrils and then breathing out through the nose), Toynbee maneuver (closing the nostrils, and subsequent swallowing). With aforementioned maneuvers it is necessary to start from the very beginning of compression phase. During this phase, the patient may experience complications such as damage of barotrauma blanks drum, sinuses, teeth, pulmonary barotrauma. The phase of compression usually does not long more than 15 minutes. Isocompression achieves the desired therapeutic pressure, the maximum allowable pressure is 3 ATA. The complication of isocompression phase may be oxygen intoxication. The duration of isocompression phase is various, at the pressure of 2 ATA it cannot exceed 180 minutes and can be repeated three times per 24 hours, at 3 ATA it may not exceed 120 minutes and may be repeated two times per 24 hours. After the time of isocompression there can occur progressive decline of the pressure in the chamber. This phase is called decompression. There also occurs a significant decrease in air temperature. The complications that may occur at this stage are similar to that of the first stage.

HBOT as the part of complex treatment has also contraindications such as open pneumothorax, acute viral infection accompanied by high fever, untreated malignant disease, claustrophobia, pregnancy, spontaneous pneumothorax in anamnesis, post-thoracic surgery in anamnesis, condition after surgery middle and inner ear, epilepsy, trauma lung cancer, emphysema, and the hyperfunction of thyroid gland [3-5].

**Respiratory Gymnastics**

Basic respiratory gymnastics represents the summary of exercises or breathing exercises that focus on the natural rhythm of breathing in coordination with some muscle movements. Special breathing gymnastics the breathing exercises are focused on deep breathing, the type of breathing and the extent of difference between the positions of breathing in the inspiratory and expiratory chest position. Special breathing gymnastics is divided into the total still breathing, combined dynamic breathing and localized breathing [6,7].

In static breathing the exercises are focused on inspiratory and expiratory respiratory muscles. The exercise deepens breathing and thus improves the mechanics of breathing. Deep inspirium and deep expirium depend on the will of a patient. We train deep inspirium when we want to improve ventilation of the lower lung. In chronic lung and bronchitis diseases we train extended deep expirium with the objection to increase the functional residual capacity that is usually reduced [8].

During dynamic breathing gymnastics we use exercises aimed at deeper breathing (deep inspirium and exspirium) combined with exercises aimed at girdle muscle groups of the upper limb, trunk and lower limb muscle groups. We co-ordinate movements with single phases of respiratory cycle [8].

The objection of localized breathing is to teach patient to control respiratory dynamics of the chest with the manual resistance affecting the selected area of the chest wall. Placing hands on that place enables physical therapist help the patient to realize, in which part he or she should breathe in. Localised breathing aims at the development of breathing in the certain part of lungs. During localized breathing we train upper thorax breathing, middle thorax breathing, chest breathing lower side, rear thorax breathing, diaphragmatic breathing and one-sided localized breathing [7].

**Case Study 1**

*Name and surname:* O.Z.; *Year of birth:* 1973;
*Basic clinical diagnosis:* G 46.2 Rear cerebral artery syndrome.
*Therapy:* HB chamber: HAUX Starmed 2200; Number of exposures: 20; Treatment pressure: +100 kPa.
*Entrance examination:* Respiratory stereotype – prevailing supine abdominal breathing, breathing in sitting position laterally. Respiratory wave – physiological during inhale and exhale. Respiratory pattern – 5:5

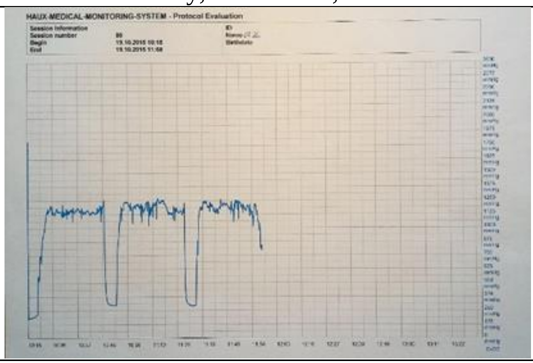
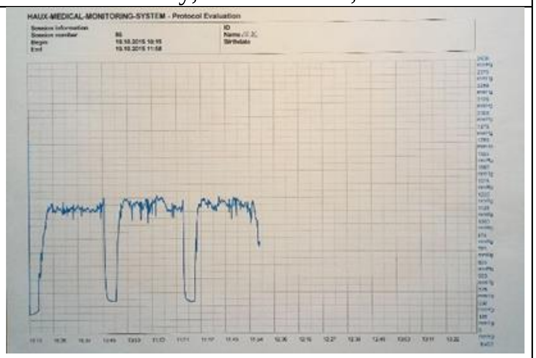
| **Exposure** | 1st day, October 19, 2015 | 20th day, November 18, 2015 |
|---|---|---|
| **Curve $ExO_2$** |  |  |
| **Average value $ExO_2$** | Approx. 1188 mmHg  Hum/noise: significant | Approx. 1269 mmHg  Hum/noise: significant |

***Figure 2:*** *Curve $ExO_2$ – Case study 1*

*Conclusion* of the curves in the first case study during exposures 1 to 20: Average value $ExO_2$: the first hour approx. 1325 mmHg; the last phase approx. 1213 mmHg. Average value of the last one $ExO_2$: approx. 1269 mmHg
Hum/noise: significant. Final evaluation of the curve $ExO_2$ is expressed in percentage. The dynamics of curve was changed in 6.8%. The final evaluation of the curve $ExO_2$ in mmHg. $ExO_2$ was increased in 81 mmHg.

**Case Study 2**

*Name and surname:* J.Z.; *Year of birth:* 1950;
*Basic clinical diagnosis:* H 91.2 *Hypacusis perceptiva l. dx.; Tinnitus l. dx.*
*Therapy:* HB chamber: HAUX Starmed 2200; Number of exposures: 10; Pressure treatment: +100 kPa.
*Entrance examination:* Respiratory stereotype – in sitting position upper pectoral. Respiratory wave – patient breathed in bully, the chest lift was less significant. Respiratory pattern – 6:7.

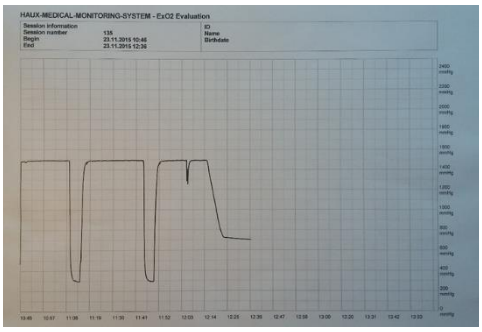
| **Exposure** | 1st day, November 9, 2015 | 10th day November 24,2015 |
|---|---|---|
| **Curve $ExO_2$** |  |  |
| **Average value $ExO_2$** | Approx. 1500 mmHg Noise/hum: low | Approx. 1500 mmHg Noise/hum: low |

***Figure 3:*** *Curve $ExO_2$ – Case study 2*

*Conclusion* of the curves in the second case study during exposures 1 to 10: Average value $ExO_2$: the first hour approx. 1500 mmHg; the last phase approx. 1500 mmHg. It was a low value $ExO_2$ and low noise since the very beginning of therapy. Thus we did not express the changes in the dynamics of curve $ExO_2$ in percentage, nor the increase of value $ExO_2$ in mmHg.

**Case Study 3**

*Name and surname:* M.F.**;** *Year of birth:* 1943;
*Basic clinical diagnosis:* S 06.1 – St.p. NCMP Hemorrhagic stroke, left hemiparesis, CHD NYHA I-II, St. after pulmonary contusion, hypercoagulable condition, chronic venous insufficiency DK,
*Therapy:* HB chamber: HAUX Starmed 2200; Number of exposures: 20; Pressure treatment: +100 kPa.
*Entrance examination:* Respiratory stereotype – in an upright sitting position in a wheelchair a patient breathing was lateral, supine abdominal breathing. Respiratory wave – physiological, from the beginning the thorax was lifted less often. Respiratory pattern – 4:5.

| **Exposure** | 1st day, February 23, 2016 | 20th day, March 18, 2016 |
|---|---|---|
| **Curve $ExO_2$** |  |  |
| **Average value $ExO_2$** | Approx. 1188 mmHg Noise/Hum: significant | Approx. 1350 mmHg Noise/Hum: reduced. |

***Figure 4:*** *Curve $ExO_2$ – Case study 1*

*Conclusion* of the curves in the third case study during exposures 1 to 20: Average value $ExO_2$: the first hour approx. 1188 mmHg; the last phase approx. 1350 mmHg. The average value of the last phase $ExO_2$: approx. 1310 mmHg. Noise: more significant mainly in the last hour. The final evaluation of curve $ExO_2$ expressed in percentage. The dynamics of the curve was changed in 10.2%. The final evaluation of curve $ExO_2$ v mmHg. $ExO_2$ was increased in 122 mmHg.

**Discussion and Conclusion**

In the selected patients with whom localized breathing gymnastics was trained, there was observed the dynamics of breathing curve which we tried to optimise through the selected breathing exercises. During the exposure in HBOT when the selected patients breathed in pure medical oxygen, depending on the diagnosis at precisely defined load (2, respectively 2.5ATM), there in isocompression phase 2 times occurred the interrupted inhalation of medical oxygen (approximately after 30 and 60 minutes of exposure) while at the same time the patients breathe about 5 minutes air, as shown in the curve during the course of respiratory curve itself.

The objection was to teach patients how to perform localized breathing. Based on theory [9] and also our experience and physiotherapy practice indicates that patients learn quite fast localized breathing while there is quite helpful to place hands on a certain part of the chest and abdominal area. The first two patients could use both hands, the third one could not for the reason of paresis of upper limb. When localized breathing is connected into one exercise, this is called the training of respiratory wave.

The change of dynamics in respiratory curve was objectified in the first and third patient in percentage. In the first patient the dynamics of the curve $ExO_2$ was changed after 20 exposures and 10 training units with the localised breathing in 6.8% without the change of noise, by the increased $ExO_2$ in 81 mmHg. In the third patient there was after 6 exposures and 5 training units with localised breathing changed the dynamics of curve $ExO_2$ in 10.2% while the noise was significantly lower in comparison with the noise during the second exposure. The $ExO_2$ value was increased in 122 mmHg. In the patient suffering with tinnitus (Case study 2) the $ExO_2$ value and low noise was observed from the very beginning of therapy, see $ExO_2$ curve. That is why we did not express the change of the dynamics of $ExO_2$ curve in percentage, nor the increased values of $ExO_2$ in mmHg. The level of noise in the last phase of the exposure was reduced what is seen from $ExO_2$ curves (Case study 2).

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