Pomeranian J Life Sci 2024;70(4):31-37 doi: 10.21164/pomjlifesci.1003

The evaluation of the efficiency and safety of hyperbaric oxygen therapy for COVID-19 in a female patient with a congenital heart disease – case study

Ada Lisowska[1, 2, 3, A] ✉, Katarzyna Szwamel [4, B], Tomasz Sochacki[5, C]

[1] Opole University, Medical Institute, Oleska 48, 45-052 Opole, Poland
[2] Opole University Hospital, Emergency Department, Wincentego Witosa 26, 45-401 Opole, Poland
[3] Opole University, Institute of Medical Sciences, Medical Faculty, Oleska 48, 45-052 Opole, Poland
[4] Opole University, Institute of Health Sciences, Katowicka 68, 45-060 Opole, Poland
[5] Rehabilitation Centre „Euromedyk", Ozimska 19, 45-057 Opole, Poland

[A] ORCID: 0000-0002-1891-0788; [B] ORCID: 0000-0001-8186-9979; [C] ORCID: 0000-0001-9295-3615

✉ ada.lisowska@o2.pl

ABSTRACT

Introduction: The study analyzed the case of a 36-year-old female patient with a congenital heart defect (patent foramen ovale – PFO; trace left-to-right shunt) who was infected by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and subjected to hyperbaric oxygen therapy (HBOT). Her post-coronavirus disease (post-COVID) symptoms included dyspnoea, deteriorated exertional tolerance, and cognitive dysfunctions. The study aimed to evaluate the efficiency and safety of HBOT in this medical case.

Materials and methods: The patient underwent the therapy according to the following schedule: 4 days of sessions, 2 days off, 3 days of sessions, 5 days off, and 5 days of sessions. The chamber pressure was 2.5 ATA and, due to the heart defect, the first 3 sessions were shortened to 45 min with a prolonged compression phase of 12 min.

Results: Right after the first session, the patient was able to walk up the stairs to her 5th-floor apartment, pausing twice without any exertional dyspnoea. After the second session, she reported significantly fewer breathing issues while walking or talking. When the HBOT was completed, her electrocardiogram (ECG) displayed steady sinus rhythm, and she had heart rate (HR) 78 beats/min, symmetrical vesicular sound, respiratory rate (RR) 105/60, SpO2 97%, and lab test results within normal limits.

Conclusions: It may be concluded that HBOT improved the clinical condition of the patient and reduced the intensity of prior symptoms, with no side effects of the therapy in the COVID-19 patient with a congenital heart defect – PFO.

Keywords: hyperbaric oxygen; therapy; safety; COVID-19 disease; congenital heart defect; patent foramen ovale.

INTRODUCTION

Over 2 million people were infected with the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the first phase of the coronavirus disease 2019 (COVID-19) pandemic [1]. The virus belongs to the *Coronaviridae* family, which is mainly characterized by high infectivity, with aerogenic and airborne transmission dominance [2]. This feature made the virus responsible for 306 million infections worldwide [3] at the beginning of 2022, including 4 million in Poland [4]. According to the initial data from China, up to 26% of those infected needed intensive therapy, and the mortality rate was 4.3% [1]. By early 2022, reports confirmed 5.5 million deaths worldwide [5].

The SARS-CoV-2 is so infectious that, despite worldwide restrictions, lockdowns, and vaccinations, it remains present in all countries. Most patients experience the infection with mild or moderately intense symptoms, primarily affecting the respiratory system. According to the World Health Organization (WHO), the major symptoms of COVID-19 include fever, cough, and loss of smell and/or taste. Sore throat, muscle pain, rash, and reddened, burning eyes are much less frequent. A fraction of the population, however, experiences a severe course of the disease with breathing difficulties that can lead to respiratory failure [6]. Research thus far has noted the occurrence of fever (82%), cough (61%), muscle pain (36%), breathing difficulties (26%), headache (12%), sore throat (10%), and digestive system symptoms (9%). The extension of the disease in the respiratory tract, observed in pulmonary tissue imaging, is reflected as ground glass opacities [7].

Depending on a patient's clinical condition, COVID-19 treatment involves symptomatic, antiviral, antibacterial, steroid, or antithrombotic medications. As a result of hypoxia and the progression of the disease, which causes difficulties in tissue oxygen diffusion, passive oxygen therapy and, in acute respiratory distress (ARDS), mechanical ventilation or extracorporeal membrane oxygenation (ECMO) are applied [8, 9, 10]. These methods allow only partial tissue oxygenation, due to the hypoxia mechanism – a disturbed normobaric oxygen diffusion from pulmonary alveoli to the capillary vessels caused by inflammation, impaired capillary perfusion, and the formation of microclots [9].

An increasing number of studies point to the beneficial effect of hyperbaric oxygen in COVID-19 treatment, as it penetrates tissues faster and more effectively, with its content in the blood being 5–10 times higher than that of normobaric

oxygen [10]. Hyperbaric therapy is based on delivering 100% oxygen at pressures higher than atmospheric pressure (over 1.4 ATA) [11], typically ranging 1.5–3.0 ATA (1 ATA = 101.3 kPa). Under normal oxygen pressure and 100% concentration, 3 mL of the gas dissolves in 1 L of plasma. At a pressure of 2.5 ATA, this amount increases to 20 mL/L as the volume of oxygen bubbles decreases [12, 13].

Research and discussions on the advisability and safety of hyperbaric therapy are ongoing in many countries [14, 15]. Opinions on the effectiveness and safety of hyperbaric oxygen therapy (HBOT) vary. Harch highlights the risks of oxygen toxicity and the danger of barotrauma or pneumothorax. He also mentions the lack of data on the duration of the therapeutic effects after treatment is discontinued [16]. Fracica et al. also report the risk of lung damage following the application of large doses of oxygen [17]. The Japanese Hyperbaric and Underwater Medicine Association is cautious, stating that HBOT is not recommended for SARS-CoV-2 patients, preferring mechanical ventilation or ECMO [18]. The European Hyperbaric Medicine Association also notes very limited case study reporting but acknowledges the possibility of reducing oxygen debt caused by ventilation/perfusion mismatch [19]. However, Petrikov et al. report that HBOT does not induce oxidative stress within therapeutic pressure levels (<2 ATA) and that hyperbaric oxygen reduces cytokine levels, which is particularly crucial during the course of the disease [9]. Other research supports the anti-inflammatory properties of HBOT, demonstrating that it inhibits inflammation by releasing cytokines and chemokines [20, 21, 22]. This effect can be observed at a pressure level of 2.4–2.5 ATA, as confirmed by studies from Bosco et al. [23] and Dulai et al. [24]. Moreover, the risk of patient intubation or mechanical ventilation decreases [25]. Researchers are also interested in the treatment of prolonged COVID-19 complications, such as fatigue, malaise [26], and cognitive disturbances (also known as "brain fog"), as oxygen positively affects brain metabolism [27]. Researchers suggest applying HBOT in COVID-19 therapy at an early stage of the disease when symptoms are mild and the cytokine storm has not yet developed [15].

As a conclusion to the above, it was decided to examine the effectiveness of HBOT in treating post-COVID symptoms such as dyspnoea, deteriorated exertional tolerance, and cognitive dysfunctions as an innovative method of COVID-19 therapy in a female patient with a congenital heart defect (patent foramen ovale – PFO) in an outpatient setting. Considering current knowledge on COVID-19 and case studies of HBOT applied exclusively to patients during the active course of the disease, during hospitalization, and without PFO, there is no clear data on the effectiveness and safety of this form of therapy.

The aim of the study was to examine the impact of outpatient HBOT on the intensity of post-COVID symptoms. The following research questions were formulated: "How did the applied protocol influence the functional status of the patient treated after SARS-CoV-2 infection?", "Is the immediate application of the proposed therapy indicated as a treatment for COVID-19 in patients with a trace left-to-right shunt (PFO)?"

MATERIALS AND METHODS

Study design

The study was carried out from May 2022 to June 2022 according to the regulations of the Declaration of Helsinki. The research was approved by the Ethics Committee of the Opole University (No. 21/2022).

Patient

The patient is a 36-year-old Caucasian female with a history of penicillin allergy. She has a chronic condition of PFO with a trace left-to-right shunt (ICD 10-Q.21.1), monitored by a cardiology clinic, without any need for pharmacological or interventional treatment. The most recent echocardiogram (6 months prior to COVID-19 infection) revealed an atrial septal aneurysm with a trace left-to--right shunt, a left ventricle without local contractility disturbances and with proper ejection fraction, a right ventricle of normal size with proper contractile function, and mild mitral valve regurgitation, tricuspid annular plane systolic excursion (TAPSE) – 2.1 cm.

The patient reported no other co-existing conditions, did not smoke (quit 1 week before the infection, previously smoked 2 packs per week for 18 years), and had a family history of breast cancer. The patient's height is 176 cm, and her weight before the infection was 59 kg.

Interventions

The hyperbaric therapy was based on delivering 100% oxygen at pressures higher than atmospheric pressure (over 1.4 ATA).

Outcome measures

The patient's medical records, including laboratory test results, cardiology clinic records, and the patient's history from the Hospital Emergency Unit, were thoroughly examined.

The study was conducted using the hyperbaric chamber O2MON23, produced by Szutest Uygunluk Degerlendirme A.S., which complies with medical requirements and the following standards: EN 14931, EN 60601-1, and EN 60601-1-2. The pressure applied was 2.5 ATA. The SARS-CoV-2 test was performed using the BD Max apparatus produced by Becton Dickinson.

To assess the level of pain, an 11-point numerical scale was applied (0–10), where 0 refers to no pain and 10 to unbearable pain [28]. The dyspnoea intensity scale modified Medical Research Council (mMRC) was used to assess the level of dyspnoea. This scale is useful in characterizing baseline dyspnoea in patients with respiratory disease. The MRC dyspnoea scale consists of 5 statements about perceived breathlessness:

- grade 1: "I only get breathless with strenuous exercise",
- grade 2: "I get short of breath when hurrying on the level or up a slight hill",
- grade 3: "I walk slower than people of the same age on the level because of breathlessness or have to stop for breath when walking at my own pace on the level",
- grade 4: "I stop for breath after walking 100 yards or after a few minutes on the level",
- grade 5: "I am too breathless to leave the house".

The patient selected the grade that applied to her [29].

Methods of analysis

The study was conducted using the case report method and included an interview technique.

CASE REPORT

Timeline

The first symptoms of SARS-CoV-2 infection appeared suddenly in the evening and included watery rhinitis and a typical scratchy feeling in the throat. At night, additional symptoms occurred such as earache, headache, severe sore throat impairing swallowing, fever of 38.5°C, muscle pain, and shivering. The patient was unable to go to work the following day. The symptoms worsened, and after 2 days, a SARS-CoV-2 RNA test was performed, yielding a positive result. The CT indicator was 17.5.

The patient underwent a 10-day isolation period at home. Initially, she received symptomatic treatment with over-the-counter medications (mainly painkillers and antipyretics such as acetylsalicylic acid – ASA, ibuprofen, and paracetamol). Despite the medications, her body temperature rose to 39°C. The antipyretic effect was only achieved after the administration of paracetamol.

The patient reported a lack of appetite and a loss of smell and taste starting on the second day of infection. She experienced sleep disturbances due to widespread body pain, which she described as unbearable (10 points on the visual analogue scale – VAS). She was only able to sleep for 6 h a day, waking up frequently. This situation significantly deteriorated her mood.

On the second day, she began experiencing dyspnoea, which made eating and talking much more difficult, if not impossible. As the patient did not have a pulse oximeter at home, the saturation values from this period of treatment are unavailable. On the fifth day, she developed a wet cough and yellow nasal secretion, and after a teleconsultation, she was prescribed erythromycin 500 mg for 5 days. Additionally, she was advised to take vitamin D3 (2000 IU) and vitamin C (1000 mg) daily. That day, the patient reported that the body pain had lessened and the fever no longer exceeded 38°C, though sleep issues persisted.

The patient had difficulty performing daily routine activities, as she was weak and tired quickly. For example, after taking a shower, she needed to rest for 2 h, and while eating, she had to pause several times due to breathing difficulties. After the infection, her body weight dropped to 56 kg, as measured on the 12th day from the onset of the illness. Around the eighth day of isolation, she partially regained her sense of taste – most meals tasted sweet, and she reported a sweet taste in her mouth even between meals.

Diagnostic assessment

After the isolation period ended, the patient went to the hospital emergency room (ER), where lab tests and diagnostic imaging were performed. On auscultation, decreased breath sounds on the right side of the lungs and crackling at the base of both lungs were found. The other examinations revealed: respiratory rate (RR) – 110/70, SpO2 – 91%, and heart rate (HR) – 120 beats/min. The chest radiogram description included the following data: pulmonary areas without lung consolidations, mediastinal structures within normal limits, normal heart silhouette, no sign of pulmonary congestion, and costophrenic angles with no pleural effusions. The chest CT was not performed.

The patient experienced walking difficulties similar to paraparesis, which she described as the feeling as if the legs were not hers, as if they were flaccid and made of wadding. This situation limited her daily functioning and efficient movement, lasting for about 4 weeks. Weakening of upper extremities occurred less frequently, but was manifested by occasional dropping of objects held in hands.

The patient also complained of cognitive impairment. She suffered from nominal aphasia for the first 3 weeks after the infection. Even after this subsided, she still experienced some verbalization and disorientation issues, especially while shopping, paying by card, or driving a car. She reported lack of ability to divide her attention, as well as problems with concentration and focus. Chronic fatigue was still present and it inhibited normal functioning.

On the second day after the isolation period ended, the patient left home. After walking 500 m she fainted, appeared pale, felt exertional dyspnoea, and was unable to continue walking, needing to sit down. She needed assistance to come back home. She was unable to climb the stairs up to her apartment located on the fifth floor. She had to pause 3 times. On the 13th day after the isolation ended, which was the 11th day since the HBOT started, she was able to walk 1 km pausing several times on the way.

RESULTS

The patient was qualified for HBOT on the third day after the isolation ended, which was the 15th day since the first symptoms appeared. Before the first session, her vital signs were near normal limits: RR – 105/69, HR – 100 beats/min, SpO2 – 93%. The mMRC scale was used to assess the level of dyspnoea. Before the therapy, the patient scored 2 at rest (due to dyspnoea, the patient walked more slowly than their peers or needed to rest to catch their breath while walking on flat ground at their own pace). After the therapy, she scored 0 (dyspnoea occurred only during strenuous physical activity). In a 6-minute walk test (6MWT), the patient was able to walk 45 m before the therapy, and after the therapy, the distance increased to 475 m. The spirometry test was also performed, and the results are presented in Table 1.

Due to the heart defect (PFO), the first 3 sessions in the hyperbaric chamber were shortened to 45 min, with the compression and decompression phases prolonged to 12 min. Initially, the dyspnoea was so severe that the patient experienced breathing difficulties while wearing an oxygen mask inside the chamber. As her tolerance improved, the therapy was extended to 60-minute sessions, with compression and decompression times of 8 min. The pressure of 2.5 ATA was applied in all sessions. Due to limited access to the HBOT facility, the patient followed this treatment schedule: 4 days of sessions, 2 days off, 3 days of sessions, 5 days off, followed by 5 days of sessions.

TABLE 1. The spirometry results

Parameter	Before HBOT	After 5 sessions of HBOT	After 10 sessions of HBOT
FVC	3.12/4.35/4.13	3.82/4.01/4.13	4.21/4.31/4.40
FEV1	2.87/2.99/2.86	2.72/3.18/3.36	2.45/3.77/3.38
PEF	2.09/3.68/3.65	2.17/3.75/3.82	2.68/6.58/6.84
FEF 25/75	1.46/2.44/2.31	1.62/2.38/2.42	1.80/3.72/3.69
FEF 25	1.64/3.11/3.23	2.08/3.27/3.82	2.97/6.11/6.18
FEF 75	0.83/1.81/1.58	1.02/1.88/1.62	1.08/1.96/1.91

HBOT – hyperbaric oxygen therapy; FVC – forced vital capacity; FEV1 – forced expiratory volume in 1 sec; PEF – peak expiratory flow; FEF – forced expiratory flow

Immediately after the first session, the patient was able to walk up the stairs to the fifth floor, pausing twice but without experiencing exertional dyspnoea. After the second session, she reported fewer difficulties with eating or talking, and after the third session, she felt significant improvements – she could eat and talk without any breathing difficulties or the need to pause. Her mood also improved.

The patient remained on sick leave until the HBOT was completed, after which she returned to work. However, 2 weeks later, due to weakness, deteriorated exertional tolerance, and dyspnoea, she visited her doctor and was given another sick leave. Her electrocardiogram (ECG) showed a steady sinus rhythm, HR – 78 beats/min, RR – 105/60, SpO2 – 97%, and she had symmetrical vesicular breath sounds. The blood test results are presented in Table 2. The doctor recommended post-COVID rehabilitation.

DISCUSSION

Scientific references contain numerous studies confirming the positive effects of HBOT on the condition of COVID-19 patients. The therapy not only improves blood oxygen saturation, boosts the amount of oxygen in less-oxygenated lung areas, and reverses tissue hypoxia, but also decreases the necessity for mechanical ventilation [25, 30, 31]. Previous reports contribute to the growing interest in confirming the therapy's safety and efficacy among patients with active SARS-CoV-2 infection. This interest has been present since the beginning of the pandemic. The first attempts to apply HBOT to COVID-19 patients were conducted in Wuhan in 2020 [32]. The therapy was applied in a hospital setting to 5 patients (4 males and 1 female) aged 24–69, with a history of coronary artery disease, hypertension, post-myocardial infarction, and diabetes. Before therapy, all patients were diagnosed with developing hypoxia (PaO2 – 61.60 mmHg, SpO2 – 73.20%) while breathing atmospheric air, along with fever. Some reported sore throat and chest pain. Pharmacological treatment included steroids, antiviral medications, and antibiotics, as well as passive oxygen therapy and non-invasive mechanical ventilation. During HBOT, the pressure ranged 1.6–2.0 ATA. The first session lasted 90 min, but subsequent sessions were shortened to 60 min. Therapy continued until 2 days after SpO2 increased above 95%. Improvement in patients' conditions was observed after the first session and was confirmed by increased blood oxygen saturation and a decrease in breathing rate from 27 to 20 breaths per minute. After 3 sessions, the oxygen debt was resolved. The authors also noted significant changes in lab blood tests before and after HBOT, particularly in lymphocytes – LYM% (9.46% vs. 20.78% on average), neutrophils – Neu% (83.62% vs. 67.98% on average), C-reactive protein – CRP (30.56 mg/L vs. 3.98 mg/L on average), D-dimer (1.84 µg/L vs. 0.42 µg/L on average), partial thromboplastin time – APTT (23.25 s vs. 26.70 s on average), and fibrinogen – FIB (4.45 g/L vs. 2.97 g/L on average). These results suggest that HBOT improves distal gas exchange, reduces clotting disorders, and prevents inflammation or cytokine storm [33].

The case examined in this study did not show elevated values for white blood cell (WBC) or CRP, but a decrease in D-dimer was observed, from 258 before HBOT to 143 after therapy completion.

Research by Liang et al. conducted in a hospitalized SARS-CoV-2 female patient also confirms HBOT effectiveness. The analysis involved a 69-year-old patient who had experienced myocardial infarction and stent implantation, suffering from a 38°C fever, chills, desaturation to 66%, and lung X-ray findings described as 'ground glass'. She underwent 7 95-minute sessions over 7 consecutive days. Her blood oxygenation increased to 99%, and the lung lesions disappeared [34].

Improvement in respiratory parameters was also confirmed by a study that examined 25 hospitalized COVID-19 patients whose infection was confirmed by polymerase chain reaction (PCR) tests. All patients had respiratory insufficiency, reduced saturation, and at least 1 risk factor (hypertension, asthma, diabetes, heart disease, obesity with body mass index – BMI >40, age >65, or chronic liver disease) [35]. The subjects received HBOT for 4 days, with 2 60-minute sessions per day at 2.2 ATA, with compression and decompression at a rate of 1 m/min. The average age of the patients was 65.44, and 60% were male. After the final session, breathing room air, a significant increase in saturation (from 89% to 93%), a decrease in the breathing rate (from 28 to 20 breaths per minute), and a reduction in CRP compared to pre-therapy levels were noted. The safety of HBOT in cardiological patients seems to be further supported by this self-reported case, in which the patient with PFO tolerated the therapy well.

TABLE 2. The lab test results

Parameter	First lab test results before HBOT	Second lab test results after HBOT	Norm
Troponin	<3.0	<0.3	<14.0 ng/L
CK-MB mass	0.77	1.12	<3.77 ng/L
Glucose	84	93	70–100 mg/dL
Serum creatinine	0.76	0.99	0.5–0.9 mg/dL
eGFR	>90	67.57	>60 ml/min/1.73m^2
CPK	49	62	<170 U/L
ALAT	18	14	<33 U/L
ASPAT	not found	16	<32 U/L
Bilirubin	not found	0.38	0.2–1.2 mg/dL
Lipase	not found	57	13–60 U/L
Amylase	not found	43	28–100 U/L
Urea	27.1	42.3	15.0–48.0 mg/dL
CRP	<1.0	<1.0	0.0–5.0 mg/L
Na	139	135	135–150 mEq/L
K	4.01	4.15	3.5–5.0 mEq/L
Cl	105	100	98–108 mEq/L
Mg	not found	2.06	1.9–2.5 mg/dL
proBNP	93.4	91.4	<116 ng/L
WBC	4.47	4.96	4.00–10.00 10^3/µL
IG%	0.2	0.0	0.0–1.0%
NE%	43.0	44.6	37.0–70.0%
LY%	40.7	38.1	20.0–45.0%
MO%	9.2	11.7	1.0–10.0%
EO%	6.5	5.2	1.0–5.0%
BA%	0.4	0.4	0.0–1.0%
IG	0.01	0.00	0.00–0.10 10^3/µL
NE	1.92	2.21	1.50–5.50 10^3/µL
LYM	1.82	1.89	1.00–4.50 10^3/µL
MO	0.41	0.58	0.03–1.00 10^3/µL
EO	0.29	0.26	0.00–0.50 10^3/µL
BA	0.02	0.02	0.02–0.10 10^3/µL
RBC	3.97	3.60	3.80–5.10 10^6/µL
HGB	13.4	12.2	12.0–15.5 g/dL
HCT	39.3	36.4	36.0–45.0%
MCV	99.0	101.1	80.0–95.0 fL
MCH	33.8	33.9	27.0–33.0 pg
MCHC	34.1	33.5	31.0–37.0 g/dL
RDW-CV	12.2	13.2	11.0–15.0%
RDW-SD	44.4	49.9	38.9–50.0 fL
PLT	313	262	150–380 10^3/µL
MPV	9.3	9.4	9.2–12.1 fL
PCT	0.29	0.25	0.19–0.41%
TSH	1.37	1.14	0.27–4.20 µU/mL

TABLE 2. The lab test results

Parameter	First lab test results before HBOT	Second lab test results after HBOT	Norm
FT3	not found	2.99	2.04–4.40 pg/mL
FT4	not found	1.28	0.93–1.71 ng/dL
PT sec	12.4	13.0	–
INR	1.09	1.16	0.8–1.2
APTT	27.4	29.8	25.0–36.0 s
Ratio	0.91	0.99	0.8–1.2
D-dimer	258	143	<500 ng/mL

HBOT – hyperbaric oxygen therapy; CK-MB – MB-type of creatine kinase; eGFR – estimated glomerular filtration rate; CPK – creatine phosphokinase; ALAT – alanine aminotransferaze; ASPAT – aspartate aminotransferaze; CRP – C-reactive protein; Na – sodium; K – potassium; Cl – chlorine; Mg – magnesium; proBNP – B-type natriuretic peptide; WBC – white blood cells; IG% – immunoglobulin; NE% – neutrophils; LY% – lymphocytes; MO% – monocytes; EO% – eosinophils; BA% – basophils; RBC – red blood cells; HGB – hemoglobin; HCT – hematocrit; MCV – mean corpuscular volume; MCH – mean corpuscular hemoglobin; MCHC – mean corpuscular hemoglobin concentration; RDW-CV – red blood cell distribution width coefficient of variation; RDW-SD – red blood cell distribution width standard deviation; PLT – platelets; MPV – mean platelet volume; PCT – procalcitonin; TSH – hyroid stimulating hormone; FT_3 – free triiodothyronine; FT_4 – free thyroxine; PT sec – prothrombin time; INR – international normalized ratio; APTT – partial thromboplastin time

Research by Petrikov et al. involved 44 men and 46 women, with an average age of 58.8 ±13.6, who were hospitalized due to SARS-CoV-2 infection and subjected to HBOT. According to the authors, 33% were in moderately severe condition, 67% were in serious condition, and 75.4% required supportive ventilation. The pressure applied ranged 1.4–1.6 ATA during 40-minute sessions. After the first session, blood oxygen saturation increased from 91.3% to 98.4% on average. After the entire course of therapy, an improvement in general condition was observed in all subjects, as well as a reduction in hypopnoea, which correlates with the self-reported case [9]. Another Russian study further supports the effectiveness of HBOT in improving respiratory parameters among hospitalized SARS-CoV-2 patients. Eighty percent of the subjects reported increased saturation, and 27.3% reported the resolution of inflammatory lung lesions. Relief from shortness of breath and general improvement were also noted. Initial sessions lasted 30 min at a pressure of 1.4 ATA, with subsequent sessions extended to 40–60 min and pressure increased to 1.6 ATA. However, some adverse side effects were observed, such as earache and claustrophobia. In the self-reported case, the patient did not experience any side effects and completed all scheduled sessions. However, 2 weeks after returning to work, she experienced weakness, dyspnoea, and deteriorated exertional tolerance again, though it remains unclear whether these symptoms were directly related to HBOT.

Gorenstein et al. selected for their study only COVID-19 patients whose saturation was below 93% while breathing room air. The group was mainly composed of men aged 30–79 with a history of coronary artery disease who required oxygen supplementation (2–15 L flow) and drug treatment (antibiotics and antivirals). The average D-dimer result was 1142, and the average CRP was 120. These patients underwent 5 90-minute HBOT sessions at a pressure of 2.0 ATA. Ninety percent of the subjects were discharged from the hospital after therapy, and none required mechanical ventilation. Ten percent of the patients were mechanically ventilated and died. Side effects noted during HBOT included epistaxis (in a patient taking anticoagulants), earache, and claustrophobia [36].

Meanwhile, research by Guo et al. aligns with the self-reported findings, confirming symptom relief such as dyspnoea and shortness of breath after the first session, with significant reduction after 7 days of HBOT. The authors examined 2 hospitalized cases – a 57-year-old woman and a 64-year-old man. Both received passive oxygen therapy, antibiotics, antivirals, and plasma. Coexisting conditions included hypertension, diabetes, and coronary artery disease. The breathing rate decreased as therapy progressed, and saturation increased to 93% after the first session and 95% by the end of therapy. Lab test results in both patients showed lower levels of D-dimer and increased levels of LYM# and LYM% after therapy [37]. Similarly, in the self-reported case, LYM% increased from 1.82 before therapy to 1.89 afterward.

Current research lacks data on cognitive disturbances and neurological deficits in COVID-19 patients, and especially on the effects of HBOT in this area. In the self-reported case, the patient reported improvements in cognitive function and walking as therapy progressed. These findings correlate with results from Raskin et al., who found that shorter therapy (fewer than 15 days) did not result in cognitive improvement [38]. Additionally, Kamat et al. suggest that the effects could be long-lasting if 40–60 min sessions were applied daily for 5 days at a pressure of 2.0–3 ATA [39].

The reference literature, however, lacks any significant data on HBOT effects in patients with heart conditions, particularly PFO. No data are available on patients treated in outpatient settings. The application of HBOT for treating COVID-19 requires further confirmation of its efficacy and safety and is currently considered experimental, although indicated [16, 26]. Ongoing research focuses on determining whether COVID-19 should be considered an indication for HBOT [40, 41].

CONCLUSIONS

Analysis of the presented method applied for the treatment of COVID-19 disease allows the following conclusions to be formulated:

1. The functional status of the patient treated with HBOT after SARS-CoV-2 infection improved.
2. Outpatient therapy using hyperbaric oxygen in a patient with a trace left-to-right shunt (PFO) improved her clinical condition and decreased the intensity of dyspnoea.

REFERENCES

1. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus – infected pneumonia in Wuhan, China. JAMA 2020;323(11):1061-9. doi: 10.1001/jama.2020.1585.
2. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med 2020;382(18):1708-20. doi: 10.1056/NEJMoa2002032.
3. WHO COVID 19 dashboard. World Health Organization. https://covid19.who.int/ (10.01.2024)
4. Koronawirus: informacje i zalecenia. Raport zakażeń koronawirusem (SARS-CoV-2). Serwis Rzeczypospolitej Polskiej. https://www.gov.pl/web/koronawirus/wykaz-zarazen-koronawirusem-sars-cov-2 (10.01.2022).
5. Coronavirus disease (COVID-19). World Health Organization. https://www.who.int/health-topics/coronavirus#tab=tab_1 (8.06.2022).
6. Geier MR, Geier DA. Respiratory conditions in coronavirus disease 2019 (COVID-19): Important considerations regarding novel treatment strategies to reduce mortality. Med Hypotheses 2020;140:109760. doi: 10.1016/j.mehy.2020.109760.
7. Senniappan K, Jeyabalan S, Rangappa P, Kanchi M. Hyperbaric oxygen therapy: can it be a novel supportive therapy in COVID19? Indian J Anaesth 2020;64(10):835-41. doi: 10.4103/ija.IJA_613_20.
8. Ghosh G. COVID-19 and HBOT: a conceptual standpoint. J Mar Med Soc 2020;22:S133-4. doi: 10.4103/jmms.jmms_112_20.
9. Petrikov SS, Evseev AK, Levina OA, Shabanov AK, Kulabukhov VV, Kutrovskaya NY, et al. Hyperbaric oxygen therapy in patients with COVID-19. General Reanimatol 2020;16(6):4-18. doi: 10.15360/1813-9779-2020-6-4-18.
10. Halbach JL, Prieto JM, Wang AW, Hawisher D, Cauvi DM, Reyes T, et al. Early hyperbaric oxygen therapy improves survival in a model of severe sepsis. Am J Physiol Regul Integr Comp Physiol 2019;317(1):R160-8. doi: 10.1152/ajpregu.00083.2019.
11. Gottfried I, Schottlender N, Ashery U. Hyperbaric oxygen treatment – from mechanisms to cognitive improvement. Biomolecules 2021;11(10):1520. doi: 10.3390/biom11101520.
12. Narożny W, Siebert J. Możliwości i ograniczenia stosowania tlenu hiperbarycznego w medycynie. Forum Med Rodz 2007;1(4):368-75.
13. Boerema I, Meyne NG, Brummelkamp WK, Bouma S, Mensch MH, Kamermans F, et al. Life without blood: a study of the influence of high atmospheric pressure and hypothermia on dilution of the blood. J Cardiovasc Surg 1959;13:133-46.
14. Łatka U, Kuliński W, Knefel G, Sieroń A. Aktualny stan medycyny hiperbarycznej w Polsce. Baln Pol 2009;1:7-17.
15. Longobardi P, Hoxha K, Perreca F. Is hyperbaric oxygen effective treatment for the prevention of complications in Sars-CoV-2 asymptomatic patients? Infect Microbes Dis 2021;3(2):109-11. doi: 10.1097/IM9.0000000000000064.
16. Harch PG. Hyperbaric oxygen treatment of novel coronavirus (COVID-19) respiratory failure. Med Gas Res 2020;10(2):61-2. doi: 10.4103/2045-9912.282177.
17. Fracica PJ, Knapp MJ, Piantadosi CA, Takeda K, Fulkerson WJ, Coleman RE, et al. Responses of baboons to prolonged hyperoxia: physiology and qualitative pathology. J Appl Physiol (1985) 1991;71(6):2352-62. doi: 10.1152/jappl.1991.71.6.2352.
18. Yanagawa Y. Current status of hyperbaric oxygen therapy for COVID-19. Acute Med Surg 2021;8(1):e678. doi: 10.1002/ams2.678.
19. EUBS & ECHM position statement on the use of Hyperbaric Oxygen Therapy (HBOT) for treatment of COVID-19 patients. European Committee for Hyperbaric Medicine. http://www.echm.org/documents/English-ECHM-EUBS-position-on-the-use-of-HBOT-for-COVID-19-1st-May-2020.pdf (8.06.2022).
20. Kjellberg A, De Maio A, Lindholm P. Can hyperbaric oxygen safety serve as an anti-inflammatory treatment for COVID-19? Med Hypotheses 2020;144:110224. doi: 10.1016/j.mehy.2020.110224.
21. De Maio A, Hightower LE. COVID-19, acute respiratory distress syndrome (ARDS), and hyperbaric oxygen therapy (HBOT): what is the link? Cell Stress Chaperones 2020;25(5):717-20. doi: 10.1007/s12192-020-01121-0.
22. Paganini M, Bosco G, Perozzo FAG, Kohlscheen E, Sonda R, Bassetto F, et al. The role of hyperbaric oxygen treatment for COVID-19: a review. Adv Exp Med Biol 2021;1289:27-35. doi: 10.1007/5584_2020_568.
23. Bosco G, Vezzani G, Mrakic Sposta S, Rizzato A, Enten G, Abou-Samra A, et al. Hyperbaric oxygen therapy ameliorates osteonecrosis in patients by modulating inflammation and oxidative stress. J Enzyme Inhib Med Chem 2018;33(1):1501-5. doi: 10.1080/14756366.2018.1485149.
24. Dulai PS, Buckey JC Jr, Raffals LE, Swoger JM, Claus PL, O`Toole K, et al. Hyperbaric oxygen therapy is well tolerated and effective for ulcerative colitis patients hospitalized for moderate-severe flares: a phase 2A pilot multi-center, randomized, double-blind, sham-controlled trial. Am J Gastroenterol 2018;113(10):1516-23. doi: 10.1038/s41395-018-0005-z.
25. Wardhani S, Suryokusumo MG, Putri NRA. Hyperbaric oxygen therapy for 'happy' hypoxia in COVID-19 patients, why is it better? Adv Health Sci Res 2020;30:110-24. doi: 10.2991/ahsr.k.201125.020.
26. El Hawa AAA, Charipova K, Bekeny JC, Johnson-Arbor KK. The evolving use of hyperbaric oxygen therapy during the COVID-19 pandemic. J Wound Care 2021;30(Sup2):S8-11. doi: 10.12968/jowc.2021.30.Sup2.S8.
27. Kim HS, Choi MH, Baek JH, Park SJ, Lee JC, Jeong UH, et al. Effects of 92% oxygen administration on cognitive performance and physiological changes of intellectually and developmentally disabled people. J Physiol Anthropol 2015;34(1):3. doi: 10.1186/s40101-015-0043-9.
28. Atisook R, Euasobhon P, Saengsanon A, Jensen MP. Validity and utility of four pain intensity measures for use in international research. J Pain Res 2021;14:1129-39. doi: 10.2147/JPR.S303305.
29. Bestall JC, Paul EA, Garrod R, Garnham R, Jones PW, Wedzicha JA. Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease. Thorax 1999;54(7):581-6. doi: 10.1136/thx.54.7.581.
30. Zhong X, Tao X, Tang Y, Chen R. The outcomes of hyperbaric oxygen therapy to retrieve hypoxemia of severe novel coronavirus pneumonia: first case report. Zhonghua Hanghai Yixue yu Gaoqiya Yixue Zazhi 2020. doi: 10.3760/cma.j.issn.1009-6906.2020.0001.
31. Zhong XL, Niu XQ, Tao XL, Chen RY, Liang Y, Tang YC. The first case of HBOT in critically ill endotracheal intubation patient with COVID-19. Beijing: Novel Coronavirus Pneumonia Research Network Sharing Platform of China Association for Science and Technology; 2020.
32. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020;395(10223):497-506. doi: 10.1016/S0140-6736(20)30183-5.
33. Yang X, Yu Y, Xu J, Shu H, Xia J, Liu H, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. Lancet Respir Med 2020;8(5):475-81. doi: 10.1016/S2213-2600(20)30079-5.
34. Liang Y, Fan N, Zhong X, Fan W. A case report of a patient with severe type of coronavirus disease 2019 (COVID-19) treated by hyperbaric oxygen: CT dynamic changes. Iran J Radiol 2020;17(4):e104475. doi: 10.5812/iranjradiol.104475.
35. Hadanny A, Shachar F, Merav C, Razia AH, Calanit K, Gabriella L, et al. Hyperbaric oxygen therapy for COVID-19 patients: a prospective, randomised controlled trial. Int J Phys Med Rehabil 2022;10(2):1000624.
36. Gorenstein SA, Castellano ML, Slone ES, Gillette B, Liu H, Alsamarriae C, et al. Hyperbaric oxygen therapy for COVID-19 patients with respiratory distress: treated cases versus propensity-matched controls. Undersea Hyperb Med 2020;47(3):405-13. doi: 10.22462/01.03.2020.1.
37. Guo D, Pan S, Wang M, Guo Y. Hyperbaric oxygen therapy may be affective to improve hypoxemia in patients with severe COVID-19 pneumonia: two case reports. Undersea Hyperb Med 2020;47(2):181-7. doi: 10.22462/04.06.2020.2.
38. Raskin A, Gershon S, Crook TH, Sathanathan G, Ferris S. The effects of hyperbaric and normobaric oxygen on cognitive impairment in the elderly. Arch Gen Psychiatry 1978;35(1):50-6. doi: 10.1001/archpsyc.1978.01770250052005.
39. Kamat SM, Mendelsohn AR, Larrick JW. Rejuvenation through oxygen, more or less. Rejuvenation Res 2021;24(2):158-63. doi: 10.1089/rej.2021.0014.
40. Harlan NP, Ptak JA, Rees JR, Cowan DR, Fellows AM, Kertis JA, et al. Development of an international, multicentre, hyperbaric oxygen treatment registry and research consortium: protocol for outcome data collection and analysis. JMIR Res Protoc 2020;9(8):e18857. doi: 10.2196/18857.
41. Kjellberg A, Douglas J, Pawlik MT, Kraus M, Oscarsson N, Zheng X, et al. Randomised, controlled, open label, multicentre clinical trial to explore safety and efficacy of hyperbaric oxygen for preventing ICU admission, morbidity and mortality in adult patients with COVID-19. BMJ Open 2021;11(7):e046738. doi: 10.1136/bmjopen-2020-046738.