



Are pulmonary bleb and bullae a contraindication for hyperbaric oxygen treatment?

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Summary

Background: Air cysts or blebs in the lungs may predispose pulmonary barotrauma (PBT) by causing air trapping when there is a change in environmental pressure. The changes in the environmental pressure are also seen during hyperbaric oxygen treatments (HBOT).

Aim: The aim of this study was to determine how patients were evaluated for pulmonary blebs or bullae, and PBT prevalence in different HBOT centers.

Methods: HBOT centers were asked to participate in this study and a questionnaire was sent via e-mail. A total of 98 centers responded to our questionnaire.

Results: Sixty-five HBOT centers (66.3%) reported that they applied HBOT to the patients with air cysts in their lungs. X-ray was the most widely used screening method for patients with a history of a lung disease. The prevalence of PBT in these centers was calculated as 0.00045%.

Conclusions: Our survey demonstrated that (1) a significant portion of the HBO centers accept patients with pulmonary bleb or bullae, (2) although insufficient, X-ray is the mostly used screening tool for patients with a history of pulmonary disease and (3) the prevalence of pulmonary barotrauma is very low in HBOT.

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Introduction

Pulmonary barotrauma (PBT) is a feared complication in situations where intrapulmonary pressure is higher than environmental pressure. Divers breathing compressed gas at depth are subject to the risk of PBT, since over-inflation

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of lungs may occur as environmental pressure is reduced during ascent. PBT is a well-established cause of arterial gas embolism in divers.¹ The changes in the environmental pressure are also seen during hyperbaric oxygen treatments (HBOT) and flights. There are a few PBT cases reported as a complication of HBOT or flights.^{2–5}

The gas in the air-containing cavities of the body will expand, in accordance with Boyle's Law, since the environmental pressure is reduced on ascent in SCUBA diving, during decompression in HBOT and during takeoff in flights. For instance, a volume of gas at 2 atm (atmosphere), will double at 1 atm, since the volume of a gas is inversely proportional with the pressure. The expanded gas in the lungs must be exhaled to prevent pulmonary over-inflation when the environmental pressure is decreased. Any reason that causes gas trapping in the lungs or breath holding while environmental pressure is decreasing may cause PBT by increasing intrapulmonary pressure. The gas trapped in the lung can rupture the alveoli by expanding. Thus, the gas in the ruptured alveoli might escape to the interstitial space, track along perivascular sheaths, and cause mediastinal emphysema, pneumothorax, or subcutaneous emphysema. If the gas enters the pulmonary circulation via torn vessels next to the ruptured alveoli, it goes to the left heart and causes arterial gas embolism (AGE). AGE is the most dangerous complication of PBT and is a major cause of mortality in diving.^{6,7}

Air cysts or blebs in the lung may predispose PBT by causing air trapping. Although there are many studies about PBT in divers who had blebs or bullae in their lungs^{8,9} a few cases of PBT during HBOT^{2,3} or flight^{4,5} were reported and these cases had preexisting lung pathologies. Air trapping lesions might be missed on plain chest X-ray examination, but can be well defined by high resolution computed chest tomography.^{9,10} There is no doubt that subjects with a known lesion in the lungs should abstain from diving because of the increased risk of PBT. However, whether lung pathologies are an absolute contraindication or not for HBOT is not clear. The aim of this study was to determine how patients with radiological evidence of pulmonary blebs or bullae were treated in different HBOT centers and the prevalence of PBT.

Methods

An internet survey was made to access the contact information of HBOT centers all around the world. Accessed HBOT centers were asked to participate in this study and the following questionnaire was sent to a total of 266 e-mail addresses.

Questionnaire

Q1 – Do you apply hyperbaric oxygen treatment to the patients having radiological evident of pulmonary blebs or bullae?

If your answer is "No" for Q1, please proceed to Q5.

If your answer is "Yes" for Q1, please answer Q2, Q3, and Q4.

Q2 – What type of chamber (multiplace/monoplace) do you use?

Q3 – What is the total number of the HBO treatment sessions done in your center approximately?

Q4 – Did you have any pulmonary barotrauma case during HBO treatment session?

Q5 – Do you radiologically screen the patients who have a history of lung disease?

A total of 98 HBOT centers responded to our questionnaire and the records of these centers were analyzed.

Results

The answering rate to the questionnaire was 36.8% (98/266). Thirty-three centers (33.7%) reported that they didn't treat the patients with air cysts in their lungs. Sixty-five centers (66.3%) stated that they applied HBOT to the patients even they had air cysts in their lungs. Twenty (30.7%) of these centers applied HBOT only for emergent cases, such as gas gangrene or decompression sickness. Twenty centers (30.7%) reported that they treat these patients after taking preventive measures. Fifteen centers (23%) applied HBOT after careful consideration of benefits and risks of the treatment for each patient. Forty-five (69.2%) of the centers who treated the patients with pulmonary air cysts used multiplace chambers, in which medical intervention is possible.

Most of the centers (18/33; 54%) which did not accept patients for HBOT were using X-ray for screening of patients with a history of lung disease. Other screening tools used by HBOT centers were computerized tomography, high resolution computerized tomography, and spirometry.

The total number of HBOT sessions done up to now in the centers included in this survey was 2 million approximately and nine PBT cases reported as a complication of HBOT. The incidence of PBT in these centers was calculated as 0.00045%. Detailed information about the PBT cases was not available.

Discussion

Air trapping lesions are regarded as contraindication for diving since they are accepted as predisposing factors for PBT. There is radiological and autopsy evidence that bullous disease may predispose to PBT in diving.^{9,11} PBT is seen mostly at shallow depths since the change in gas volume is higher in proportion to pressure change, according to Boyle's Law. For example 6 l volume of gas at 2 atm becomes 12 l at 1 atm. But the volume of 6 l of a gas at 3 atm becomes 9 l at 2 atm. While the pressure change is 1 atm in both conditions, volume changes are higher in the first condition. The pressure in the chamber changes between 1 and 3 atm during the HBOT sessions. This range of pressure is enough to cause PBT in diving. But physical conditions in HBOT application are different than the conditions in diving. First of all, the decompression rate is markedly slower than the rate in diving. In diving, excluding submarine escape training, the decompression rate is around 1 atm/min. But in HBOT the decompression rate is usually not faster than 0.1 atm/min. On the other hand the breathing gas is 100% oxygen if the patient doesn't remove the mask during the decompression. In addition, one should consider that the immersion affect makes the lung mechanics differ between diving and HBOT. Immersion increases air trapping in lungs, which is a risk factor for

PBT, as the hydrostatic pressure itself and hydrostatic pressure induced blood shift into thorax compresses the lungs.¹²

To our knowledge, there are a few cases who had PBT as a complication of HBOT.^{2,3} There is also another PBT complication that occurred after a dive by using oxygen rebreathing apparatus.⁸ In this type of dive, divers breathe oxygen and don't go deeper than 10 m (2 atm). In this aspect, profile of the pressure changes is similar to that of HBOT. But probably the decompression rate is faster. They have detected a small subpleural emphysematous bulla in this diver by spiral computed chest tomography. Clinical outcome of pulmonary barotrauma in the case of oxygen rebreathing may be different from that in compressed air diving, due to the altered gas physics. Oxygen can be absorbed and metabolized while nitrogen remains until it is washed out.

The questionnaire we performed among hyperbaric centers revealed that 66% of the responded centers do treat the patients with HBOT even though the patients have bleb or bullae. Forty-five (69.2%) of these centers reported that they use multiplace chamber. It is an advantage to use multiplace chambers, in case of an emergency during HBOT, since it is possible to enter to the chamber for medical intervention. The HBOT centers accepting patients with blebs reported that they were taking some preventive measures when such a patient is treated. These preventive measures include using slower compression and decompression rates, limiting the treatment pressures at 2 atm, using bronchodilators prior to the treatment, following up the patient closely and keeping the required equipments for thoracentesis in case of pneumothorax.

Seven centers reported nine PBT cases as a complication of HBOT. In one case it was reported that it was a complication of subclavian catheterization. There were preexisting lung pathologies such as tumor in two cases. Mechanical ventilation failure and endotracheal tube obstruction were the reasons for the two cases. Detailed information about the other cases was not available. It is also possible that in some cases contemporary spontaneous pneumothorax may be regarded as PBT caused by the HBOT. The prevalence of PBT was calculated as 0.00045% among the centers joined to this survey.

Some centers reported that they didn't treat the patients if they had bullae or bleb. But they also stated that they do routine screening by chest X-ray. We know now plain chest X-ray doesn't show such lesions efficiently.⁹ It means that some patients with air cysts in lungs, especially the ones who didn't have any clinical symptoms previously, might be accepted for HBOT, since none of the centers use chest computerized tomography as routine screening.

Our survey demonstrated that a significant portion of the HBO centers accept patients with pulmonary bleb or bullae, although insufficient, X-ray is the mostly used screening tool for patients with a history of pulmonary disease and the prevalence of pulmonary barotrauma during HBOT is very low. For the selected indications, HBOT may be administered without screening for air trapping lesions, if there is no clinical evidence of a current lung disease.

Conflict of interest statement

None of the authors have a conflict of interest to declare in relation to this work.

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