Pulmonary Barotrauma in a Free Diver Who Breathed Compressed Air at Depth: Case Report

Derinde Basınçlı Hava Soluyan Serbest Bir Dalgıçta Pulmoner Barotravma

Akın Savaş TOKLU, MD, Prof.,[a]
Ahmet HOBEK, MD, Msc.,[a]
Mustafa ERELEL, MD, Prof.,[b]
Alper TOKER, MD Prof.[c]

Departments of
[a]Underwater and Hyperbaric Medicine,
[b]Pulmonary Diseases,
[c]Thoracic Surgery,
İstanbul University
İstanbul Faculty of Medicine,
İstanbul

Geliş Tarihi/*Received:* 25.02.2010
Kabul Tarihi/*Accepted:* 03.11.2010

Yazışma Adresi/*Correspondence:*
Akın Savaş TOKLU, MD, Prof.
İstanbul University
İstanbul Faculty of Medicine,
Department of Underwater and Hyperbaric Medicine, İstanbul,
TÜRKİYE/TURKEY
akin@toklu.net

ABSTRACT Pulmonary barotrauma (PBT) usually develops in Self Contained Underwater Breathing Apparatus (SCUBA) divers if there is air trapping during ascent caused by uncontrolled decompression, breath holding and emerging of air trapping in the lungs. The air expanded in lungs according to the Boyle's Law should be exhaled enough during ascent to prevent PBT. A 36 years-old-male diver made breath-hold diving to 9 meters. He breathed compressed air from the equipment of a SCUBA diver at the same depth. Afterwards he surfaced leaving the SCUBA diver and did not exhale during ascent. Some air came out of his lung involuntarily before reaching the surface. He had chest pain, dysarthria and sensory changes at surface. Although his neurological complaints disappeared within 30 minutes, substernal pain persisted. The chest computed tomography (CT) scan revealed mediastinal emphysema that disappeared in 3 weeks without treatment. In this case, the diver neglected to exhale the expanded air in the lung during ascent.

Key Words: Barotrauma; diving; embolism, air

ÖZET Pulmoner barotravma (PBT) genellikle Self Contained Underwater Breathing Apparatus (SCUBA) (Kendi Üzerinde Taşınabilen Sualtında Soluma Aygıtı) dalgıçlarında yükseliş sırasında kontrolsüz dekompresyon nedeniyle hava tıkacı varsa, nefes tutulursa ve akciğerlerde hava tıkacı ortaya çıkarsa görülür. PBT'yi önlemek için, akciğerlerde Boyle kanununa göre genişleyen hava, yükseliş sırasında yeterince dışarı verilmelidir. Otuz altı yaşındaki erkek bir dalgıç 9 metre derinliğe nefes tutarak dalış yapmıştır. Dalgıç dipte aynı derinlikte bulunan bir SCUBA dalgıcının donanımından basınçlı hava solumuştur. Ardından SCUBA dalgıcını aşağıda bırakarak yüzeye gelmiş ve çıkış esnasında soluk vermemiştir. Yüzeye ulaşmadan hemen önce akciğerlerinden istemsiz olarak bir miktar hava çıkmıştır. Yüzeyde göğüs ağrısı, konuşma bozukluğu ve duyu kusurları ortaya çıkmıştır. Substernal ağrı dışındaki nörolojik şikâyetleri 30 dakikada kaybolmuştur. Göğüs tomografisinde mediastinal amfizem tespit edilmiştir; amfizem, 3 hafta içinde herhangi bir tedavi yapılmaksızın düzelmiştir. Bu olguda dalgıç, çıkış esnasında akciğerlerde genişleyen havayı dışarı vermeyi ihmal etmiştir.

Anahtar Kelimeler: Basınç travması; dalma; emboli, hava

Turkiye Klinikleri J Med Sci 2012;32(1):255-9

Pulmonary barotrauma (PBT) is a risk for people when intrapulmonary pressure is higher than environmental pressure. This complication can develop in mechanical ventilated patients, divers and aviators or airline passengers.[1,2] PBT is especially a risk for divers who breathe compressed gas while immersed at pressure, like Self Contained Underwater Breathing Apparatus (SCUBA) or surface supplied divers. On ascent, the gas in the air containing cavities of the body will expand, in accordance with Boyle's Law, since environmental pressure is reduced during ascent. A volume of gas at 10 meters, where the pressure is 2 atmospheres absolute (ATA), will double at

doi: 10.5336/medsci.2010-17849

the surface since the pressure is decreased to 1 ATA. The expanded gas in the lungs must be exhaled to prevent pulmonary overinflation during ascent. Breath holding during ascent or any reason that causes air trapping in the lungs may cause PBT by increasing intrapulmonary pressure. The alveoli can be ruptured when the lungs get overinflated. The gas may escape from the ruptured alveoli to the interstitial space, track along perivascular sheaths, and cause mediastinal emphysema, pneumothorax, or subcutaneous emphysema.[3] If the gas enters the pulmonary circulation via torn vessels next to the ruptured alveoli, it may reach the left heart and cause arterial gas embolism (AGE). AGE is the most dangerous complication of pulmonary barotrauma and is a major cause of mortality in diving.[4]

Breath-hold diving has been popular particularly over the past decade, as a recreational sport. This type of diving is performed for competitive purpose or spearfishing. Recently the depth of free diving and duration of breath holding of competitors has reached to 200 meters and 11 minutes respectively. Breath-hold diving is associated with a variety of physiological responses induced by immersion, apnea and lung compression.[5] Normally pulmonary overinflation is not an issue during breath-hold diving, in contrast to lung squeeze, which is the result of the increased pressure to the constant gas volume in the lung. Compared with compressed air diving, PBT is extremely rare in breath-hold diving. Nevertheless, it can develop in a breath-hold diver if there is an increase in intrathoracic pressure due to a reason like coughing.[5] Normally, a breath holding diver does not breathe compressed gas while immersed at pressure. Here we report a case that started diving by breath holding, but breathed compressed gas while at the bottom and experienced PBT during ascent. The patient was informed about this case report and related permission was taken.

CASE REPORT

An otherwise healthy 36-year-old-man made breath-hold diving three times to 3-5 meters without any problem. He made his last dive to 9 meters, while his friend was underwater with SCUBA gear at the same depth. He approached to his friend and took his extra regulator to share his air, when he was short of breath. After breathing several times, he left his friend and started to ascent. He ignored to exhale while ascending and he felt pressure increase in his thorax at 4-5 meters. Some air came out of his lung involuntarily when he was about to surface. He felt substernal pain, jerking and sensational change in the right lower extremity and right side of his body at surface. He could hardly be withdrawn to the boat and he felt weakness in his right lower extremity. He had dysarthria, which subsided within 10 minutes. His complaints almost completely disappeared within 30 minutes except the chest pain. An ambulance was available within 30 minutes and the treatment was set with oxygen administration with nasal prongs, dexamethasone 8 mg intramuscularly and infusion of electrolyte solution during the transfer to the hospital. At the hospital, tele-consultation with a diving physician was made and PBT was suggested as the presumptive diagnosis. Recompression treatment was recommended together with 100% oxygen administration during the transfer. A high-resolution computed chest tomography (HRCT) was recommended as well. The patient was referred to the nearest center for HRCT, which revealed normal results (Figure 1). The patient re-

FIGURE 1: Chest X-ray on the day of accident.

ported that substernal pain decreased within 30 minutes following the initiation of treatment. There was no pathological finding reported after the examination at the hospital where the HRCT was performed. He was discharged in the evening on the same day and he presented to the Department of Underwater and Hyperbaric Medicine, İstanbul Faculty of Medicine next day, since he had slight chest pain while breathing.

On examination, the patient was afebrile, blood pressure was 120/70 mm Hg, pulse was 77 beats/min, and respiration rate was 15 breaths/min. He appeared anxious but there was no pathological finding on physical examination. Mediastinal emphysema findings were detected in his chest HRCT (Figure 2) and X-Ray. Pulmonary diseases and thoracic surgery specialists consulted the patient for treatment. There was no recommendation except prohibition of diving. The patient was asked for control with CT scan of chest in three weeks. The mediastinal emphysema had disappeared in the control CT scan (Figure 3). He was recommended not to resume breath-hold diving for 6 months. There was no pathology detected during the control after six months and he started breath-hold diving gradually.

DISCUSSION

During decreases in ambient pressure, the higher pressure of the gas inside the air spaces causes damage to the surrounding tissues if it becomes trapped. Pulmonary barotrauma usually develops in SCUBA divers if there is air trapping during ascent caused by uncontrolled decompression, breath holding and existence of an air-trapping lesion in the lungs. Therefore the term “never hold your breath” is

FIGURE 2: Chest computed tomography scan on the day of accident.

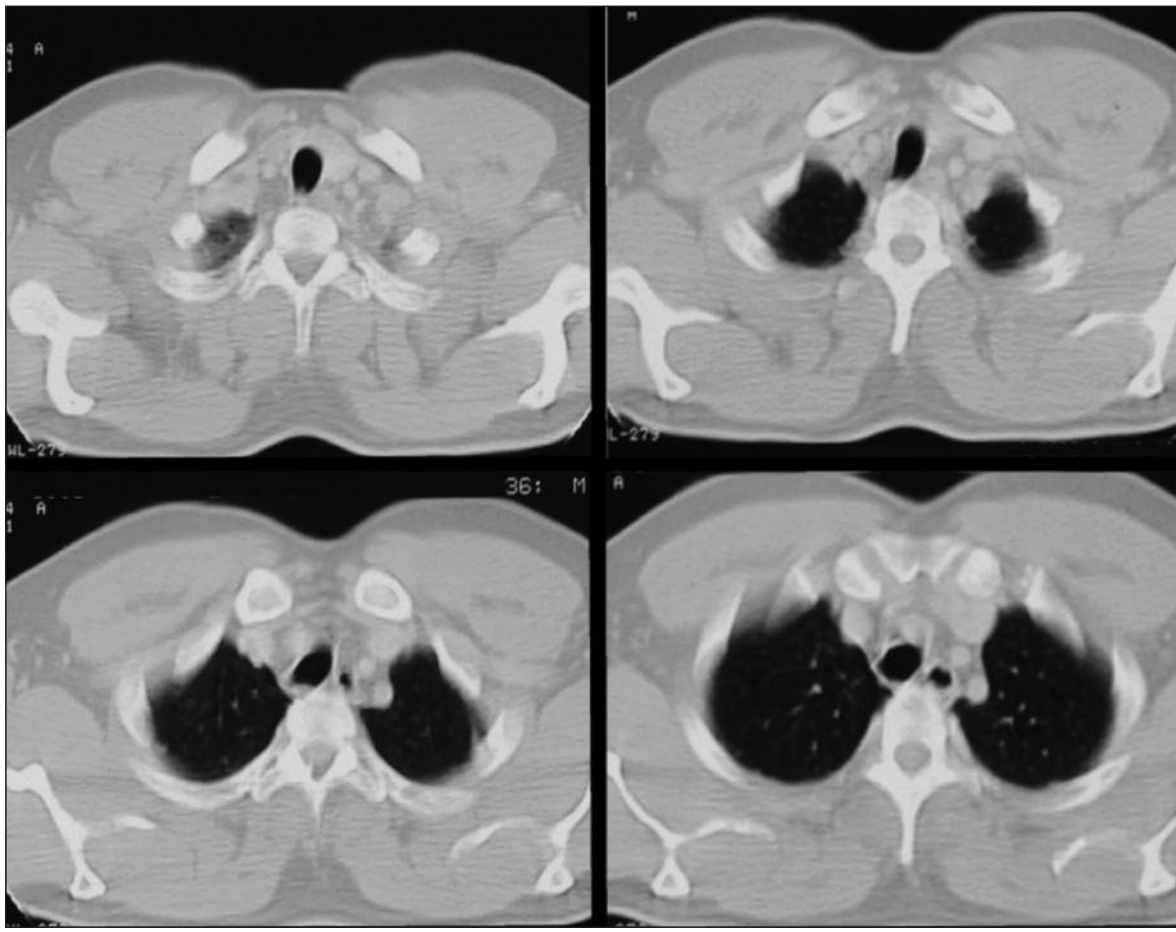

FIGURE 3: Chest computed tomography scan after 3 weeks.

taught as a golden rule during SCUBA dive training. The expanded air in the lungs should be exhaled enough during ascent to prevent PBT.

In breath-hold diving the volume of the lungs is decreased according to the Boyle's Law, since the ambient pressure is increased during descent. On the way back to the surface the volume of lungs returns to its original value while the ambient pressure is decreased during ascent. If the environmental pressure is high enough to squeeze the lungs to the volume lower than the residual volume, the negative pressure in the lungs may give damage to pulmonary tissues. This type of barotrauma seen in breath-hold diving is termed as lung squeeze or pulmonary descent barotrauma. Lung overinflation normally is not expected in breath-hold diving. Nevertheless, if there is a maneuver that increases the intrapulmonary pressure like coughing, PBT may occur even in breath-hold diving.[6] In our case there was not such a maneuver, but there was a very risky action that should be avoided by all breath-hold divers. The inhaled volume of the air in the lungs will reach almost double at the surface if the diver breathes compressed air at nine meters. The diver did not exhale during ascent and the expanded air ruptured alveoli and escaped to the mediastinum.

It was part of the SCUBA training to leave the diving gear at depth and come to surface by exhaling the expanded air about 20-25 years ago. As it was found very risky, this practice was left for sportive divers and only submariners had similar periodic training. Submariners do exercise by breathing compressed air at 60 feet depth and come to surface by exhaling in submarine escape training tank (SETT). The risk of this training is docu-

mented well.[8,9] Breath-hold divers usually have nothing to do with compressed air while they are under the water. Rarely it is possible to see some young people who dive by breath holding and share the air of a SCUBA diver for fun, at the bottom where they do SCUBA training. Some of them are conscious of the risk and keep exhaling during ascent. In this report, the diver ignored to exhale, but excess volume of air escaped from his mouth involuntarily. The diver is not a SCUBA diver and he was not trained for SCUBA diving. Therefore, he was not aware of the risk of breathing compressed air at the depth and ascent afterwards.

In PBT cases, it is critical to administer 100% oxygen during the first aid and transport. In this case, the oxygen was given by nasal prongs, an unsuitable route to deliver 100% oxygen. Oxygen should be given by mask with reservoir bag or other 100% oxygen delivery systems in such cases. Some PBT cases may recover spontaneously.[6] In this case, neurological symptoms subsided without recompression therapy. When there is a suspicion of PBT, a recompression facility should be saught since the clinical conditions may deteriorate. The nearest recompression facility was at about 5 hours drive for this case. The patient was not referred to a hyperbaric facility, probably since there was no neurological finding at the time of examination. On the other hand, mediastinal emphysema was clear in HRCT and this finding should have been enough reason to seek for recompression therapy.

There are several forms of PBT; mediastinal emphysema, subcutaneous emphysema, pneumothorax and arterial gas embolism (AGE). Sometimes PBT cases may be asymptomatic. Symptoms and signs usually appear within an hour after the dive.[2] While symptoms like substernal pain and coughing may point out mediastinal emphysema, AGE may cause neurological symptoms. In this case, neurological symptoms like dysarthria and sensational changes were more likely due to AGE. The substernal pain was due to mediastinal emphysema that was confirmed by HRCT. The free gas around the peribronchial and perivascular area and mediastinum was reabsorbed within three weeks without any treatment. HRCT is a valuable measure in determining the extent and presence of mediastinal emphysema. Plain chest radiographs were shown in one Japanese study to miss small pneumomediastinums.[10] In this case, chest CT scanning was helpful in confirming the diagnosis as well as determining the extension of air in mediastinum, which could be done by chest radiographs.

REFERENCES

1. Anzueto A, Frutos-Vivar F, Esteban A, Alía I, Brochard L, Stewart T, et al. Incidence, risk factors and outcome of barotrauma in mechanically ventilated patients. Intensive Care Med 2004;30(4):612-9.
2. Francis TJR, Denison DM. Pulmonary barotrauma. In: Lundgren CEG, Miller JN, eds. The Lung at Depth. 1st ed. New York: Marcel Dekker; 1999. p.295-374.
3. Şen E. [Drowning, near-drowning, decompression illness, barotrauma]. Turkiye Klinikleri J Surg Med Sci 2006;2(11):100-4.
4. Schench HV, McAniff JJ. United States underwater fatality statistics. 1972. Report No. URI-73-8. NOAA grant no. 4-3-159-31. Kinston, RI: University of Rhode Island; 1972.
5. Fitz-Clarke JR. Adverse events in competitive breath-hold diving. Undersea Hyperb Med 2006;33(1):55-8.
6. Shah S, Thomas S, Gibb E. Pneumomediastinum after shallow water diving. J Emerg Med 2009;36(1):76-7.
7. Neuman TS. Arterial gas embolism and decompression sickness. News Physiol Sci 2002;17:77-81.
8. Brooks GJ, Green RD, Leitch DR. Pulmonary barotrauma in submarine escape trainees and the treatment of cerebral arterial air embolism. Aviat Space Environ Med 1986;57(12 Pt 1):1201-7.
9. Lafère P, Germonpré P, Balestra C. Pulmonary barotrauma in divers during emergency free ascent training: review of 124 cases Aviat Space Environ Med 2009;80(4):371-5.
10. Fujiwara T. Pneumomediastinum in pulmonary fibrosis. Detection by computed tomography. Chest 1993;104(1):44-6.