

Pulmonary Problems & Diving

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Diving related Lung Conditions.

Any form of acute illness may of course occur during diving. Trauma, oxygen toxicity, or hypoxia due to equipment malfunction or poor dive planning and hypothermia are also potential risks for the diver. But there are four specific types of diving related illness of the lung: pulmonary barotrauma (PBT), arterial gas embolism (AGE), decompression sickness (DCS) and pulmonary oedema associated with immersion. The risk of fatal accidents in diving is below hang gliding and parachuting but above most recreational sports. How are these conditions related? You should discriminate decompression illness (DCI), decompression sickness (DCS) Type I and II, AGE and PBT. DCI subsumes DCS and AGE. DCS I refers to skin and joints. DCS II to organs like lungs, heart and nervous system. AGE is the most dangerous and fatal condition. It can develop in case of DCS or in PBT.

Pulmonary Barotrauma (PBT)

A barotrauma is the result of compression of a gas filled body cavity during descent, or expansion during ascent. Organs particularly at risk include the ear, the sinuses, and the lung. Boyle's Law ($p \cdot V = k$) explains the mechanism of PBT: 10m of water exerts the same pressure as the atmosphere, or 1 bar. Thus if one starts off for example with a TLC (total lung capacity) of 6 litres on the surface and one descends to a depth of 10 m without breathing any additional gas, the volume of gas in the lungs will be halved to 3 litres. However, if one should breathe from a gas source at 10 m, the volume of the lungs is 6 litres there, but will double when the diver ascends to the surface. This enlarging volume of gas is usually exhaled, but should there be some reason that the gas is not exhaled (i.e., breath holding), then mechanical forces can result in disruption of lung parenchyma causing one of the pulmonary overinflation syndromes pneumothorax, pneumomediastinum, skin emphysema and even AGE. On the other hand, PBT on descent results in compression of the lung in a breath hold dive or rapid descent when breathing equipment has failed and may lead to alveolar exudation, haemorrhage and wall rupture leading to cough, haemoptysis, and dyspnoea.

Decompression sickness (DCS)

results from gas dissolving in body tissues under pressure ($p \cdot V = k$). During a dive, the increased pressure causes nitrogen from the air to dissolve in tissues. When ascending the pressure surrounding the pressure decreases and the excess nitrogen can't stay in solution, it forms bubbles in the tissues and in vessels, which are normally filtered in the lungs. Bubbles can form in different tissues in the body, thus DCS symptoms will vary. Pulmonary decompression sickness is the result of sudden, massive blocking the pulmonary arterial circulation by bubbles. White blood cells attach to bubbles, leukocytes are activated resulting in leakiness of blood vessels, lung oedema and ARDS (Adult respiratory distress syndrome).

Role of the lung in arterial gas embolism (AGE)

A paradoxical embolism will occur in patients with PFO, but also when the pulmonary vascular filter is leaking or when the lung is injured by PBT. Normally in venous gas embolism (DCS) the bubbles are filtered in the lung. If there is a right-left shunt in the lung, or more common a PFO (Patent foramen ovale) blood can flow in both directions at various phases of the cardiac cycle. In addition, a Valsalva maneuver used by divers to equalize their ears can increase venous atrial pressure to the point that it forces blood containing bubbles across the PFO into the arterial circulation. Thus the usual filtering process of the lungs is by-passed.

Pulmonary oedema associated with immersion

is an acute pulmonary oedema in divers during the course of a dive. The cause is unclear. But there is an association with hypertension. And repeated episodes have been reported. Symptoms often become more marked during the ascent phase of the dive, partly as a result of the falling oxygen tension in the breathing gas, and may continue to deteriorate after surfacing. Haemoptysis often occurs and symptoms may persist for 24–48 hours after the dive. Individuals with this history should be advised against further diving.

Recommendations for assessing respiratory fitness to dive

The medical history of aspiring divers is most important. You should ask for current respiratory symptoms, previous and chronic lung conditions, previous chest trauma, previous spontaneous pneumothorax and lung surgery. Respiratory examination and spirometry should be performed. Chest Radiography is recommended on first exam, in subjects with smoking history, and if any pulmonary condition has occurred after first exam. Previous spontaneous pneumothorax is a contraindication unless treated by bilateral surgical pleurectomy and associated with normal lung function and thoracic CT scan performed after surgery. More contraindications: COPD (II)III-IV, lung emphysema, lung cysts and bullae, fibrotic lung disease, pleural adhesions and scars of lung tissue after lung surgery, ...

SCUBA Diving with **asthma** is discussed controversially. On the one hand there is theoretical risk of air trapping and resulting PBT and AGE. In addition cold dry air inhaled from the regulator during the dive could lead to an asthma attack and cause severe dyspnoea. However, there is little if any evidence of higher risk for mild and controlled asthmatics. The recommendation from British Thoracic Society guidelines on respiratory aspects of fitness for diving. *Thorax 2003; 58:3-13* doi:10.1136/thorax.58.1.3 are widely accepted: Subjects with asthma should be advised not to dive if they have wheeze precipitated by exercise, cold, or emotion. Subjects with asthma may be permitted to dive if, with or without regular inhaled anti-inflammatory agents are free of asthma symptoms; have normal spirometry (FEV1 >80% predicted and FEV1/VC ratio >70% predicted); and have a negative exercise test (<15% fall in FEV1 after exercise). Subjects with asthma should monitor their asthma with regular twice daily peak flow measurement and should refrain from diving if they have: uncontrolled asthma with symptoms requiring relief medication in the 48 hours preceding the dive; reduced PEF (more than 10% fall from best values); increased peak flow variability (more than 20% diurnal variation).