Pulmonary Fitness for Diving and Hyperbaric Exposure

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Pulmonary risks in diving

- Barotrauma (pressure lesions)
  - Pneumothorax
  - Pneumomediastinum
  - Arterial Gas Embolism
- Gas exchange $O_2$ – $CO_2$
  - Pulmonary oedema – hypoxemia
- Gas exchange inert gases
  - Decompression sickness

Acceptability of Risk

- Probability x Severity of consequences
- Appreciation of “acceptable risk” = variable
- Therefore, no definite guidelines (fitness to dive with pulmonary disease) exist

- Difference in risk evaluation according to diving activity (recreational diving vs. Sports diving vs hyperbaric work vs hyperbaric patients)
Examples of “Fit to Dive” criteria

- toutes les formes d’asthme,
- les pneumothorax et les «trappes à air» pulmonaires,
- les infections pulmonaires,
- toutes maladies, malformations ou opérations réduisant les échanges pulmonaires

Contre-indications Absolues
- Insuffisance respiratoire
- Pneumopathie fibrosante
- Vascularite pulmonaire
- Pneumothorax spontané ou maladie bulleuse, même opéré
- Chirurgie pulmonaire
- Asthme

Contre-indications Relatives
- Pathologie infectieuse
- Pleurésie
- Traumatisme thoracique

Relative Risk Conditions

- History of Asthma or Reactive Airway Disease (RADD)
- History of Exercise Induced Bronchospasm (EIB)
- History of solid, cystic or resecting lesion
- Pneumothorax secondary to:
  - Thoracic Surgery
  - Previous Overinflation Injury
- Obesity
- History of Immersion Pulmonary Edema Restricted Disease
- Interstitial lung disease: May increase the risk of pneumothorax
- Spontaneous should be advised on before and after exercise
- Active Reactive Airway Disease, Active Asthma, Exercise Induced Bronchospasm, Chronic Obstructive Pulmonary Disease or history of same with abnormal PFTs or a positive exercise challenge are contraindicated for diving.

Severe Risk Conditions

- History of spontaneous pneumothorax. Individuals who have experienced spontaneous pneumothorax should avoid diving, even after a surgical procedure designed to prevent recurrence (e.g. pleurodesis). Surgical procedures either do not correct the underlying lung abnormality (e.g. pleurodesis, apical pleurectomy) or may not totally correct it (e.g. resection of lesions or tumors).
- Impaired exercise performance due to respiratory disease.
Basis of most recommendations

BTS GUIDELINES
British Thoracic Society guidelines on respiratory aspects of fitness for diving
British Thoracic Society Fitness to Dive Group, a Subgroup of the British Thoracic Society Standards of Care Committee*

• Old ? But still valid & well balanced

Minimal requirements for divers

• Medical history
  - current respiratory symptoms
  - previous history of lung disease incl. childhood
  - previous trauma to the chest
  - previous episodes of pneumothorax

• Respiratory system clinical examination

• Lung function tests
  – FEV1, FVC, FEV1/FVC (Tiffeneau)
  – Flow-Volume Loop*
  – Provocation testing (exercise provocation) at slightest doubt!


Pulmonary requirements for divers

• Chest X-ray – in case of symptoms / history (required for professional divers)
• Chest HRCT: air-trapping, bullae

• Asthmatics
• Spontaneous pneumothorax
• Bullae / blebs
Asthmatics and diving

• Risk = bronchospasm during diving
  – Already present before diving
  – Induced by diving (breathing cold air, increased turbulent flow by effort and pressure, salt water spray inhalation)
• Decreased exercise capacity → exhaustion
• Air trapping → pulmonary barotrauma
• Bronchodilators may increase pulmonary bubble passage → DCS
• Consequences = severe = unacceptable?

Asthmatics do dive

• Divers Alert Network: no increased prevalence of asthmatics in DCS and PBT statistics
• Prevalence of asthma may be as high as 30% in general population
• Several (low quality studies) suggest that many asthmatics dive without (too much) problems

Mebane GY. The coincidence of asthma and morbidity or mortality in recreational scuba divers reported to DAN. UHMS 1996.
Farrell P et al. Diving practices of scuba divers with asthma. BMJ 1990; 300:166

Asthmatics can dive

• British Thoracic Society Guidelines 2003
  – Free of symptoms with/without medication
  – Normal spirometry (FEV1 >80%, FEV1/FVC >70%)
  – Negative exercise provocation test (8 minutes exercise 70-80% of max; breathing compressed air, <15% decrease of FEV1)
  – NO DIVING if
    • requiring medication <48hrs or
    • PEF decrease >10% from best value or
    • increased PEF variability >20% diurnal

Provocation testing

• Direct provocation tests (histamine, metacholine, hypertonic saline): may be positive in 10-12% of healthy population
• Of those, (only) approx. 20% will test positive on exercise provocation
• Pulmonary function tests should be APPROPRIATE for divers and COMPLETE
### Spirometric abnormalities
- Spirometric value thresholds vary according to source (BTS vs SPUMS vs...)
- Tiffeneau value: dependent on age, body size, race
- “Large lungs” – spirometry values > 120% of normal value
  - Van Hulst et al. 2011: 6 cases of PBT in military divers
  - Subject selection or diving induced abnormality?
  - All had also CT evidence of air trapping, bullae or blebs

### Spontaneous pneumothorax
- Risk = pneumothorax while at depth
  - Spontaneous
  - Breathing against resistance
  - Equal Pressure Point shifting = hyperinflation
- Consequences:
  - Tension pneumothorax
Spontaneous pneumothorax

- Recurrence rate, after initial drainage:
  - 35% → 54% total recurrence rate,
  - 25% of recurrences contra-lateral lung
  - 75% of recurrences within 2 years but even after 6-8 years (18%)

- Pleurodesis or not:
  - Simple drainage: 38.5% recurrence
  - Chemical pleurodesis: 26.5%
  - Surgical pleurodesis (pleurectomy): 0 – 0.5%

Recommendations BTS 2003

- Spontaneous pneumothorax = contra-indication to all diving
- UNLESS
  - Treated with BILATERAL surgical pleurectomy
  - AND associated with normal lung function (Flow-Volume Loop) and thoracic HRCT scan

- For recreational divers ???
  - Federation guidelines differ – mostly: NO

Pulmonary Bullae - Blebs

- Risk = overinflation upon ascent
  - Pneumothorax
  - Pneumomediastinum
  - Arterial Gas Embolism

- Risk factors:
  - Congenital
  - Infectious
  - SMOKING
Diagnosis of bullae = HRCT

Discussion point

- "Isolated" bullae → no risk?
- "Thick-walled" → no risk?
- Note: Evidence for increasing size of bullae with diving (years)

Case report

27 Apr 1997: Immediately after diving and symptoms of cerebral arterial air embolism.
19 Nov 1997: After 6 months - reduction of bulla volume.
29 Jun 2002: Stable volume after 5 years (no diving).
Case report: residual air space after pleurodesis

Proposed mechanism

- Descent (Boyle's Law):
  - Bulla volume decreases
  - Relative underpressure (elasticity limit of bulla wall)

- Isopression:
  - Diffusion of inert gas into bulla
  - Equipressure after variable amount of time (30+ minutes ?)

- Ascent (Boyle's Law):
  - Bulla volume increases
  - Bulla wall stretches
  - Relative overpressure in bulla
  - Gradual return to normal volume
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- **Cyclic !**
- **At one point, bulla wall “overstretches” during / after ascent → Pulmonary Barotrauma**

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**Evaluation of asymptomatic, isolated, pulmonary bulla: HRCT, PFT !**

- **Location ?** Apical vs. juxtapleural vs intrapulmonary
- **Size ? > 1cm**
- **Other pulmonary abnormalities** (pleural adhesions, air-trapping), Flow Volume Loop ?
- **Clinical history ?**
  - Pneumothorax
  - Pulmonary barotrauma
  - Smoking, asthma
- **Diving history (years, dives)**
- **In case of doubt, repeat CT scan after x months diving ?**

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**Pulmonary symptoms after diving ?**

- **Recognise & treat as a possible emergency !**
- **Contact hyperbaric / diving medicine specialist**
  - 24/24 Hotline for diving emergencies
  - Toll-free number (Belgium)
  - Telephone advice only
  - Referral to HBO centre in case of need