Some Diving Physics and Physiology; Barotrauma

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Occupational Health Risk Management Services Ltd
Oil & Gas UK (EBS) conference

24th May 2017

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Why me?

- Former Senior Medical Inspector for HSE (Scotland)
  - Diving and offshore knowledge portfolio
  - Auditor of HSE AMEDs in Scotland and UK
- Provided advice to OPITO on EBS
- Maintained AMED competencies with regular CPD
- NOT a diver myself!
Introduction to EBS and risks

- Some principles and physics:
  - Pressure change is key
- Principle risks to health from submersion in water:
  - Damage from pressure → **Barotrauma**
  - Any ‘diving’ less than 10 m depth → No risk of decompression illness (anything to do with inert gas diffusion out of tissue on ascent).
Back to school, some Physics

- Pressure at depth can be measured in:
  - Pressure absolute → at sea level = 1 atmosphere absolute (ATA, 1 bar)
  - (Pressure gauge → at sea level = 0 (ATG))
- Column of 10 m sea water = ± 1 ATA (depending on salinity, temp)
- So: going from the surface to depth changes the pressure from:
  - Surface → 10 m depth: change from 1 ATA at surface to 2 ATA
  - 10 m → 20 m depth: change from 2 ATA to 3 ATA
  - 80 m → 90 m: change from 9 ATA to 10 ATA
Why we can dive at all?

- Pascal’s principle (fluid law):
  - “A pressure exerted anywhere in a confined incompressible fluid is transmitted in all directions….such that the pressure ratio remains the same (→ principle of hydraulics)
  - Muscle, bone, tendons: incompressible

- Submersion (even surface swimming): fluid shift from legs to thorax (700-800ml): impact on lung elasticity
  - Responsible for diuresis; changes in pulmonary ventilation

- Air filled space are a bit more problematic
  - Risk of barotrauma
Why EBS? Risk of sudden emersion

- ± 70% of all drowning victims drown within 2 m of the shore, mostly from sudden incapacitation due to inhalation of water and secondary complications
- Previous system: exhale own breath into flexible reservoir and rebreathe from there → timing critical and difficult if already submerged
- EBS: several breaths possible, can be deployed under water, essentially SCUBA; less complex (?) --> training. Canadian experience.
Boyle’s Gas law and submersion

- If temperature (T) remains constant, then the volume of a given mass of gas is inversely proportional to the absolute pressure;
- In other words: in a closed system =>
- $P \times V = K(\text{constant})$ or $P_1 \times V_1 = P_2 \times V_2$
- Pressure rises $\rightarrow$ volume goes down
- Pressure decreases $\rightarrow$ volume increases.
- Bases for Barotrauma
Example of pressure change when scuba diving

- Say 10 L air at the surface (= at 1 ATA)
  - At 2 ATA (= 10 m depth) → 5 L
  - At 5 ATA (= 40 m depth) → 2 L
  - At 10 ATA (= 90 m depth) → 1 L

- Note: the greatest relative pressure change occurs in the first 10 m!

- Key for health risk: pressure change; up or down (going deeper or surfacing)
Organ systems at risk

- Any **gas** filled spaces in the body
  - Lungs
  - ENT system: ear and sinusses
- The risk?:
- Something going POP!
Lungs

- Gas escape from alveoli:
  - ‘normal’ (low risk?) pneumothorax: gas “escape” into any anatomical space
    - Pleura; if progression --> tension pneumothorax
    - Mediastinum
    - Retroperitoneal
  - **High risk**: gas escape into the circulation
    - Arterial Gas Embolism (AGV) → has occurred at 1 m water depth swimming
      - Coronary artery embolus
      - Brain circulation embolus: gross neurological signs: LOC, seizures, ‘stroke’ symptoms
    - Potentially lethal but risk in pool doing EBS is thought to be very low
Lungs

- Acute Non Cardiogenic Pulmonary Oedema:
  - Immersion:
    - Divers, surface swimmers (Wilmshurst 1981: hypertension, asthma, COPD), cold water ↑
  - Non-Immersion:
    - Tri-athletes (non-immersion?):
      - ↑female,
    - (Race horses)
    - High Altitude Pulmonary Oedema (‘altitude sickness’)


At EBS practical depths

- Maximum ‘dive/submersion depth’ = < 70 cm
  - 50 cm = 0.05 ATA (50/100=0.5 m)
  - \( P_1 \times V_1 = P_2 \times V_2 \)
  - 1 ATA * 1 L = 1.05 * V2 \( \rightarrow \) V2 = 0.95 L; 1L at surface is now 950 ml at 50 cm depth
  - Breath at 50 cm depth going to the surface:
    - 1L breath at depth \( \rightarrow \) at surface 1.05 L \( \rightarrow \) 50 ml expansion/L
Who could be at risk?

- Contentious but, people with:
  - (Known) Bullae;
  - COPD, (pulmonary) hypertension?
  - Asthma?
  - Large PFO? (> 11 mm, ‘significant’ crossover?)

- Screening??
  - Commercial divers: CXR not required
  - Submarine escape training: inverse correlation with FVC
Britich Thoracic Society

- Even in series of military divers (very fit):
  - 20 year period → 120 cases; one fatal
- Asthma: pool dive scuba training < 5 m: 2 AGE cerebral circulation (case report; BTS reference)
- Post mortem: adhesions and lung bullae seen
- Patients with past spontaneous pneumothorax → less ‘distensible’ lungs?
Offshore Helicopter Passengers
The known ‘unknowns’

- General fitness?
- Bias in disclosure of health problems/medication?
  - Self treatment? OTC or OTC abroad
- International public:
  - Previous long haul flight (cold, respiratory infections)?
  - Doing survival refresher a day before flying offshore?
To be expected?

- Primarily ENT
  - Cerumen related
  - Failure to equalise middle ear
  - Sinus ‘squeeze’;
- Lung? → likely exceedingly rare but not completely impossible
- ‘High risk’ (ENT, lung or otherwise) candidates
  → review with specialist
References

- CAP 1145
- http://www.lakesidepress.com/pulmonary/books/scuba/sectionf.htm