Complications of Hyperbaric Oxygen Therapy

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Complications of Hyperbaric Oxygen Therapy

- Related to effects of pressure on enclosed gas spaces
- Related to oxygen toxicity
- Psychogenic effect
- Others
Complications of Hyperbaric Oxygen Therapy

- Related to effects of pressure on enclosed gas spaces (Barotrauma)
  - Ear barotrauma
  - Sinus barotrauma
  - Pulmonary barotrauma
  - Other barotrauma

- Related to oxygen toxicity

- Psychogenic effects

- Others
Barotrauma

- Although human tissues may support great pressure, tissue injury can occur
- resulting from failure of gas-filled space to equalize its internal pressure with ambient pressure changes
- Boyle’s Law
Barotrauma

- Diving activities, compressed-air work, aviation and hyperbaric therapy

- Injury is most likely when
  - Pressure-volume changes are great
  - Onset is rapid – as occurs during initial parts of pressurization or descent from atmospheric pressure
Barotrauma

- Two conditions must be present for barotrauma to occur
  - Change in ambient pressure
  - Transfer of pressure to a non- or partially collapsible airspace
Barotrauma

- In particular may affect middle ear and sinuses; lung; intestines; teeth; eye, particularly when surrounded by air space like a face mask; and other physiological or pathological gas spaces
Ear barotrauma
External ear barotrauma
External ear barotrauma

- External ear canal
  - 3.5 cm long and 1 cm wide
- Barotrauma of canal and eardrum are possible
  - because ambient and outer ear pressures cannot be equilibrated
  - Usually external ear is filled with water or air at ambient pressure
- With blocked canal (e.g., by an ear plug or wax) pressure changes during descent and ascent
  - possible injury of epithelial lining of the external meatus and TM, with edema, hemorrhage and rarely perforation of eardrum
External ear barotrauma

- Other causes include external ear infection, exostoses; foreign bodies; and tight-fitting neoprene diving hoods.
- Pain is made worse by clearing ears.
  - Mild conductive deafness and vertigo may be present until pressure is relieved.
- Otoscopy reveals an ear canal that is swollen with hemorrhagic blistering; bleeding is possible.
BLEEDING and TISSUE SWELLING into CANAL

1 ATA
AIR at 1 ATA
EAR PLUG or WAX

2 ATA
EAR PLUG or WAX PUSHED INWARDS
EARDRUM BULGES OUTWARDS
Middle ear barotrauma
Middle ear barotrauma

- Middle ear cavity communicates with nasopharynx through Eustachian Tube (ET) – a 4 cm long tube
- Under normal conditions tube is opened by chewing, swallowing or yawning due to action of controlling muscles
- Allows equalization to occur between middle ear and nasopharyngeal air pressure
Middle ear barotrauma

- Closure of ET is passive process and it is collapsed in its natural state
- Passive escape of gas occurs when middle ear pressure is around 4 cm H2O higher than ambient pressure
Middle ear barotrauma

- Rarely spontaneous equalization during increasing ambient pressure and this is why barotitis media may occur
- Most common diving and hyperbaric medical complication
Equal Air Pressure

Unequal Air Pressure
Middle ear barotrauma

- Otological barotrauma of descent is characterized by
  - initial sensation of ear blockage
  - followed by sharp pain

- If swelling, bleeding or perforation
  - occurs this may be accompanied by a conducting hearing loss, mild tinnitus and vertigo
Middle ear barotrauma

6 grade severity classification by Edmonds

- Grade 0 - Symptoms without otoscopic signs
- Grade 1 - Diffuse redness and retraction of TM
- Grade 2 - Grade 1 changes plus petechial hemorrhage TM
- Grade 3 - Grade 1 changes plus confluent/plaque hemorrhage in TM
- Grade 4 - Dark and slightly bulging TM: free blood or fluid in middle ear
- Grade 5 - TM perforation with possible blood in our outside ear canal
Middle ear barotrauma

- Treatment depends on degree of barotrauma
- Avoided exposure to pressure
- Recovery usually occurs over 3 to 14 days
- Topical and systemic nasal decongestants
- Pain relief
- Rupture TM → systemic broad spectrum antibiotic
- Large perforations, especially those associated with deafness or tinnitus → referred to ENT
Middle ear barotrauma

- Middle ear barotrauma of ascent
  - for ET dysfunction to cause air trapping
  - TM bulging outwards
- May cause asymmetrical stimulation of the vestibular apparatus with alternobaria vertigo of ascent (called Lündgren Syndrome)
- Self-limiting form of transient dizziness usually occurs during ascent
- It is less common during descent
- Although transient, vertigo, disorientation and nausea – usually lasting less than 10 minutes – may present serious problems for divers, particularly at depth
Middle ear barotrauma

- Alternobaric facial paralysis
  - transient unilateral facial paralysis in association with ipsilateral middle ear overpressure
  - Mechanism: facial nerve neuropraxia
  - Full facial nerve function usually returns to normal within 2 hours of returning to atmospheric pressure
  - Diving is not recommended
  - Myringotomy is advised
Inner ear barotrauma
Inner ear barotrauma

- Using forceful Valsalva’s maneuvers
- May elevate intracranial and inner ear hydrostatic pressure sufficiently to cause rupture of inner ear structures
  - Basement membrane rupture, or round and/or oval windows may be involved
Inner ear barotrauma

- Rupture of round window leads to a **perilymph leak** into middle ear → **perilymph fistula**
- Extremely rare in hyperbaric medicine practice
- History of
  - serious vertigo
  - intense tinnitus
  - sensation of fullness in ear
  - sensory-neural hearing loss
  - nausea and vomiting
  - positive Romberg sign
  - nystagmus
Inner ear barotrauma

- **Treatment:**
  - Bed rest with elevated → reduce ICP
  - Evaluated with audiogram, electronystagmogram and be submitted to complete otorhinolaryngological and neurological evaluation
  - Hyperbaric exposures should be avoided until complete clinical recovery
  - If it is essential to continue HBO, → myringotomy
Sinus barotrauma
Sinus barotrauma

- Related to inadequate pressure equilibration in gas volumes of sinus cavities
- Ostial obstruction with inadequate gas passage between nasal cavity and sinuses
Sinus barotrauma

- Cause of obstruction: mucus, nasal polyps, congestion of nasal mucosa, foreign bodies, nasal structural deformities or mass lesions,
  - sinus barotrauma of descent (sinus squeeze) or ascent (reverse sinus squeeze)
  - frontal and maxillary sinuses being the most commonly affected
Sinus barotrauma

- Hydrostatic pressure is transferred throughout body
- Higher than pressure within gas space
- Relative vacuum phenomenon occurs with blood vessel dilatation
- Possible rupture and hemorrhage in sinus space
Sinus barotrauma

- Main symptom is pain, which may persist for several hours
  - Associated with bloody nasal discharge
- Paresthesia of cheek or forehead may occur with maxillary or frontal sinus squeeze respectively
- Due to compression of branches of fifth cranial nerve
- Pain may be referred to occipital region with sphenoid sinus barotrauma
Sinus barotrauma

- Function of pressure
  - Valsalva’s maneuvers, over-pressurized sinus cavity may lead to migration of air to the cranium or infra-orbital plate fractures with ophthalmic involvement and – rarely – pneumocephalus
  - Meningitis and blindness rare but have been reported
  - Again there are no known references to these severe complications during HBO therapy
Pulmonary barotrauma
Pulmonary barotrauma

- Pulmonary barotrauma results from pulmonary overexpansion in response to a reduction in ambient pressure
- Intra and extravascular intrapulmonary gas migration follow with various potential complications
Pulmonary barotrauma

- Pulmonary overpressure is most frequent cause of arterial gas embolism
- Relatively common in diving (approximately 10% of diving accidents)
- Very rare in hyperbaric medicine practice
- Causes include rapid decompression and high positive pressure ventilation
Pulmonary barotrauma

- Arterial gas embolism
- Pneumothorax
- Pneumo-mediastinum
- Subcutaneous emphysema
Pulmonary barotrauma

- Gas may exert local pressure effects or cause cerebral and coronary arterial gas embolism (AGE)
- Most dangerous complication
Pulmonary barotrauma

Risk of barotrauma
- during decompression
- decreased pulmonary compliance
- previous spontaneous pneumothorax
- acute lower respiratory infection
- Atelectasis
- bullous emphysema
- pulmonary cysts
- blunt chest trauma
- sub-pleural blebs
- pulmonary fibrosis
- COPD with air trapping
- Many of these conditions may not be adequately excluded by CXR
Pulmonary barotrauma

- Management, depending on severity
- Includes:
  - 100% O2 by oronasal mask
  - Emergency drainage of a tension pneumothorax by needle thoracostomy
  - Definitive management of intrapleural gas or blood is ICD
    - If HBO is required, Heimlich one-way valve should be connected to drainage system
    - If recompression is not required → regular underwater drainage is appropriate
  - Pericardial drainage for gas tamponade with needle pericardiocentesis
Other barotrauma
Other barotrauma

Barodontalgia (Tooth or dental barotrauma)

- characterized by pain or injury during changes in ambient pressure
- mechanism involved may be related to expansion of trapped air in a cavity underneath crown of tooth with pain receptor activation
  - stimulation of nerve endings in chronic inflamed pulp
  - stimulation of maxillary sinus pain receptors.
Other barotrauma

Gastrointestinal Excessive swallowing of gas (i.e., aerophagia) during decompression

- Rare, occur due to expansion of air in stomach and bowel, causing abdominal distension and colicky pain.
Other barotrauma

ocular barotrauma

- Hx of ophthalmic surgical procedures
  - have gas in anterior chamber or vitreous cavity
- This may be affected by pressure changes with resulting barotrauma including
  - retinal, uveal or vitreous hemorrhage and possibly partial globe collapse
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- Related to oxygen toxicity
- Psychogenic effect
- Others
Complications of Hyperbaric Oxygen Therapy

- Related to effects of pressure on enclosed gas spaces
- Related to oxygen toxicity
  - Neurological oxygen toxicity (CNS toxicity)
  - Pulmonary oxygen toxicity
  - Ocular oxygen toxicity
- Psychogenic effect
- Others
Oxygen toxicity
Oxygen toxicity

- mechanism of oxygen toxicity is unknown.
- hyperoxia has been demonstrated to depress cellular metabolism.
- Many enzymes are inactivated by high Po2
  - sulphhydryl groups\((-SH)\) \(\rightarrow\) glyceraldehyde phosphate dehydrogenase (key enzyme in glycolysis)
- Gamma-aminobutyric acid (GABA)
  - hyperoxia is a reduction in the endogenous output of GABA. This decrease is thought to produce the convulsions
- The oxygen free radical theory of toxicity
The diagram illustrates the processes of lipid peroxidation and free radical pathology. Oxygen (O₂) is produced by mitochondria and catalase. Superoxide (O₂⁻) is converted to hydrogen peroxide (H₂O₂) by superoxide dismutase (SOD), which is then converted to hydroxyl radical (OH⁻) by glutathione peroxidase and glutathione reductase. Glutathione (GSH) is oxidized to glutathione disulfide (GSSG), and this cycle is essential for detoxification. Lipid peroxidation leads to enzyme cross-linkage damage, membrane damage, organelle damage, cell damage, and disease.
In diving and diving medicine, oxygen toxicity is possible in the following situations:

- Closed and semi-closed rebreathing equipment.
- Use of high Fio2 mixtures ('technical diving').
- Oxygen therapy for diving disorders.
- Therapeutic recompression.
- Respiratory failure (drowning).
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<td>● ? Inert gases</td>
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CENTRAL NERVOUS SYSTEM TOXICITY
Clinical manifestations

- Twitching (especially of the lips)
- Nausea
- Dizziness
- Tinnitus
- Tunnelvision
- Dysphoria
- Convulsions

*no reliable warning of impending convulsions*
Factors lowering threshold to CNS toxicity

- Severe exercise
- Immersion in water, rather than chamber
- Hypothermia
- Increased arterial carbon dioxide from any cause
Prevention of convulsions by anaesthetics or anticonvulsant agents removes only this overt expression of toxicity, and damage at the cellular level will continue.

The Royal Navy and Royal Australian Navy place a limit for pure oxygen diving of 9 metres for a resting dive and 7 metres for a working dive.
Treatment

- A void physical trauma associated with a grand mal convulsion
- In the water, the diver should be brought to the surface
- Reduce the oxygen in his breathing mixture.
PULMONARY TOXICITY
Clinically obvious pulmonary oxygen toxicity does not manifest in short-duration.

Prolonged exposures to partial pressures as low as 0.55 ATA have been found to produce significant changes. A Pio2 of 0.75 ATA has produced toxicity in 24 hours.
Clinical manifestations

**Pulmonary oxygen toxicity**

- Chest tightness or discomfort
- Cough
- Shortness of breath
- Chest pain
The measurement of forced vital capacity (FVC or VC) is one monitor of the onset and progression of toxicity especially at higher inspired oxygen pressures (2.5ATA), demonstrate a rapid fall in VC. 

CXR : no pathognomonic appearance of oxygen toxicity.
Figure 17.2 Relationship of partial pressure of oxygen breathed, and duration of exposure, to degree of pulmonary oxygen damage.
Prevention

- No specific therapy
- When toxicity is evident, the oxygen partial pressure should be reduced
- Intermittent exposure may delay the onset of toxicity.
OTHER MANIFESTATIONS OF TOXICITY

O Haemopoietic system
  O abnormal cell morphology and/or a decrease in circulating red blood cell mass
  O depression of erythropoiesis
  O Inactivation of essential glycolytic enzymes or damage to red cell membranes

O Eye
  O retinopathy of prematurity in infants
  O decrease in peripheral vision
  O Cataract formation
  O Retinal detachments, retinal micro-infarcts
OTHER MANIFESTATIONS OF TOXICITY

- Vasoconstriction
  - Raynaud's phenomenon
  - Buerger's disease
  - migraine.

- Ear
  - A syndrome related to the middle ear
  - The symptoms were fullness, popping or crackling sensation in the ear, and a mild conductive hearing loss

- Cancer
  - enhance tumour development.

Ref: Diving and Subaquatic Medicine 4th
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- Related to effects of pressure on enclosed gas spaces
- Related to oxygen toxicity
- Psychogenic effect
  - Claustrophobia
  - Anxiety
  - Stress
- Others
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- Others
Complications of Hyperbaric Oxygen Therapy

- Related to effects of pressure on enclosed gas spaces
- Related to oxygen toxicity
- Psychogenic effect
- Others
  - Hypoglycemia
THANK YOU