Reference

- Diving and Hyperbaric Ophthalmology (Major Review)
- Captain Frank K. Butler, Jr., MD
- Online Summary:
SCUBA
Self-Contained Underwater Breathing Apparatus
Regulator Maintenance
Rebreather

- Open, semi-closed, closed circuits
- Open: CO2 exhaled in bubbles
- Inefficient use of O2, worsens with depth
- Closed circuit rebreather (CCR):
  - Counterlung for expansion, volume mvt
  - CO2 absorber (LiOH…)
  - O2 regulator
  - Upstream and downstream check valves
  - Shut-off valve (H2O exposure)
Boyle’s Law

- $P_1 V_1 = P_2 V_2$ or
- $P_1 V_1 = \text{Constant}$
- Temperature is constant
SCUBA Diving

- **Boyle’s Law** \( P_1 V_1 = P_2 V_2 = \text{Constant} \)
  - Temperature is constant
  - During descent, \( P \) increases so \( V \) decreases
    - Eg. Face mask barotrauma / sucking
  - Re-expansion occurs during ascent
    - Eg. Intraocular gas expansion / CRAO; Lung rupture

- **Henry’s Law** of gas solubility in liquids
  - Eg. Decompression sickness

\[
P_{\text{gas}} = kC \quad \text{at constant } T
\]

\[
\frac{C_1}{P_1} = \frac{C_2}{P_2}
\]

- Low pressure equilibrium
  - Low concentration
- Double the pressure equilibrium
  - Double the concentration
Face Mask Barotrauma

- Compression of the air in the mask results in a relative vacuum
### TABLE 4
**Ophthalmic Contraindications to Diving**

1. Intraocular gas
2. Presence of a hollow orbital implant
3. Any acute infectious or inflammatory ocular disorder which produces significant pain, photophobia, diplopia, or decrease in vision
4. Recent ophthalmic surgery prior to completion of the recommended convalescent period
5. Inadequate vision to function safely in the underwater environment
6. Visually significant deficits from previous episodes of decompression sickness or arterial gas embolism
7. Functioning glaucoma filter (relative contraindication)

### TABLE 3
**Recommended Minimum Convalescent Periods Prior to Diving after Ophthalmic Surgery**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Recommended Convalescent Period</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Anterior segment surgery</em></td>
<td></td>
</tr>
<tr>
<td>Penetrating keratoplasty</td>
<td>6 months</td>
</tr>
<tr>
<td>Corneal laceration repair</td>
<td>6 months</td>
</tr>
<tr>
<td>Cataract surgery</td>
<td></td>
</tr>
<tr>
<td>Non-corneal valve incision</td>
<td>3 months</td>
</tr>
<tr>
<td>Corneal valve incisions</td>
<td></td>
</tr>
<tr>
<td>Clear corneal</td>
<td>2 months</td>
</tr>
<tr>
<td>Scleral tunnel</td>
<td>1 month</td>
</tr>
<tr>
<td>Radial keratotomy</td>
<td>3 months</td>
</tr>
<tr>
<td>Astigmatic keratotomy</td>
<td>3 months</td>
</tr>
<tr>
<td>Glaucoma filtering surgery</td>
<td>2 months</td>
</tr>
<tr>
<td><strong>(Relative contraindication)</strong></td>
<td></td>
</tr>
<tr>
<td>Photorefractive keratectomy</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Pterygium excision</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Conjunctival surgery</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Corneal suture removal</td>
<td>1 week</td>
</tr>
<tr>
<td>Argon laser trabeculoplasty or iridectomy</td>
<td>No wait necessary</td>
</tr>
<tr>
<td>Yag laser capsulotomy</td>
<td>No wait necessary</td>
</tr>
<tr>
<td><em>Vitreoretinal surgery</em></td>
<td></td>
</tr>
<tr>
<td>Vitrectomy</td>
<td>2 months</td>
</tr>
<tr>
<td><strong>(Diving contraindicated until intraocular gas resorbed)</strong></td>
<td></td>
</tr>
<tr>
<td>Retinal detachment repair</td>
<td>2 months</td>
</tr>
<tr>
<td>Pneumatic retinopexy</td>
<td>2 months</td>
</tr>
<tr>
<td><strong>(Diving contraindicated until intraocular gas resorbed)</strong></td>
<td></td>
</tr>
<tr>
<td>Retinal cryopexy or laser photocoagulation for breaks</td>
<td>2 weeks</td>
</tr>
<tr>
<td><em>Oculoplastic surgery</em></td>
<td></td>
</tr>
<tr>
<td>Sutured wound</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Skin graft or granulating wound</td>
<td>Until epithelialization is complete</td>
</tr>
<tr>
<td>Enucleation</td>
<td>2 weeks</td>
</tr>
<tr>
<td><strong>(Diving contraindicated with hollow orbital implants)</strong></td>
<td></td>
</tr>
<tr>
<td><em>Strabismus surgery</em></td>
<td>2 weeks</td>
</tr>
</tbody>
</table>
Henry’s Law

Solubility of gases in liquids

- Nitrox 78% N2, 21% O2
- Less toxicity, fewer decomp. stops, less fire hazard than high O2

\[ P_{\text{gas}} = kC \text{ at constant } T \]

\[ \frac{C_1}{P_1} = \frac{C_2}{P_2} \]
# Decompression Sickness

Table 1. Signs and symptoms of decompression sickness.

<table>
<thead>
<tr>
<th>DCS Type</th>
<th>Bubble Location</th>
<th>Signs &amp; Symptoms (Clinical Manifestations)</th>
</tr>
</thead>
</table>
| BENDS    | Mostly large joints of the body (elbows, shoulders, hip, wrists, knees, ankles) | - Localized deep pain, ranging from mild (a "niggle") to excruciating. Sometimes a dull ache, but rarely a sharp pain.  
- Active and passive motion of the joint aggravates the pain.  
- The pain may be reduced by bending the joint to find a more comfortable position.  
- If caused by altitude, pain can occur immediately or up to many hours later. |
| NEUROLOGIC | Brain | - Confusion or memory loss  
- Headache  
- Spots in visual field (scotoma), tunnel vision, double vision (diplopia), or blurry vision  
- Unexplained extreme fatigue or behaviour changes  
- Seizures, dizziness, vertigo, nausea, vomiting and unconsciousness may occur, mainly due to labyrinthitis |
| Spinal Cord | Abnormal sensations such as burning, stinging, and tingling around the lower chest and back  
- Symptoms may spread from the feet up and may be accompanied by ascending weakness or paralysis  
- Girdling abdominal or chest pain |
| Peripheral Nerves | Urinary and rectal incontinence  
- Abnormal sensations, such as numbness, burning, stinging and tingling (paresthesia)  
- Muscle weakness or twitching |
| CHOKES | Lungs | - Burning deep chest pain (under the sternum)  
- Pain is aggravated by breathing  
- Shortness of breath (dyspnea)  
- Dry constant cough |
| SKIN BENDS | Skin | - Itching usually around the ears, face, neck arms, and upper torso  
- Sensation of tiny insects crawling over the skin  
- Mottled or marbled skin usually around the shoulders, upper chest and abdomen, with itching  
- Swelling of the skin, accompanied by tiny scar-like skin depressions (pitting edema) |
TABLE 1

Ocular Manifestations of Decompression Sickness

1. Nystagmus
2. Diplopia
3. Visual field defects
4. Scotoma
5. Homonymous hemianopia
6. Orbicularis oculi pain
7. Cortical blindness
8. Convergence insufficiency
9. Central retinal artery occlusion
10. Optic neuropathy
Altitude DCS!

- In excess of 18,000 feet (standard commercial flight!)
- O2 mask 100%O2
- Emergency decent (Continue O2!)
  - Resolution confirms the diagnosis! So, don’t stop Rx!
- If joint pain occurs, keep the area still
- Be your own advocate; hyperbaric specialists are rare!
- Delayed onset of symptoms can occur
- Do not fly for 24 hours after the event
- Always allow min. 24 hours between flight and diving
- Divers Alert Network (DAN) (USA) 919-684-4DAN
Causes of Acutely Decreased Vision After Diving (Table 2)

- Decompression sickness
- Arterial gas embolism
- Displaced contact lens
- Anti-fog keratopathy
- Ultraviolet keratitis
- Corneal edema from bubbles under PMMA or RGP contact lenses
- Contact lens adherence syndrome
Thank You