Scuba Diving 101
Diving Injuries

Carol Scott, MD
UNR Student Health Sports Medicine
SCUBA - self contained underwater breathing apparatus

5 million sport scuba divers in U.S.

250,000-400,000 new certifications annually in U.S.

Diving occurs in oceans, freshwater lakes, rivers and quarries
Pre-dive exams for new certifications

Diving related injuries and emergency care

- Even if don’t practice near dive site, many patients may return home with dive related problems

Certification to continue diving

FP, IM, ED, Anesthesia, Psychiatry, ENT, Pulmonary, Cardiology, Neurology, Dermatology all care for divers
Dive with a buddy
History of Diving

- 500 BC - Breath hold diving
- 1530 Diving bell - surface air
- 1828 Diving suit - surface air
- 1873 Caisson disease - building Brooklyn Bridge
- 1941-44 Scuba - closed circuit
- 1946 Cousteau’s Aqua Lung - open circuit
SURFACE SLOWLY...SAFETY STOP!
Diving Related Injuries

- Hydrostatic pressure changes
- Hypothermia
- Breathing challenges/drowning
- Mobility
Diving Related Injuries

- Decompression sickness
- Air embolism
- Nitrogen narcosis
- Loss of consciousness often fatal due to drowning
Diving Related Injuries

- Annual deaths approximately 100
- Injuries .53-3.4 incidents per 10,000 dives
Don’t hold your breath!
Human body mostly water

Pressure is distributed equally

Hollow and gas containing organs very sensitive to pressure changes

Lungs, sinuses, middle ear
Change in atmospheric pressure most important factor to affect divers.

Atmospheric pressure at sea level = 14.7 pounds per square inch absolute or 760mm Hg.

At 33 feet in salt water, pressure on diver is DOUBLED.

1 atmosphere addition each 33ft.
Air Pressure vs Water Pressure

50 miles of atmosphere
1 inch square = 14.7 lbs.

33 feet sea water
1 inch square = 14.7 lbs.

At Sea Level:
- 1 cu.ft. air = .083 lbs.
- 1 cu.ft. sea water = 64 lbs.
# Pressure Changes With Depth

<table>
<thead>
<tr>
<th>Depth in FSW</th>
<th>Pressure in ATM</th>
<th>Volume of air in balloon</th>
<th>Density of air in balloon</th>
<th>Relative size of balloon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level</td>
<td>1</td>
<td>12</td>
<td>1x</td>
<td><img src="image" alt="Balloon" /></td>
</tr>
<tr>
<td>33</td>
<td>2</td>
<td>6</td>
<td>2x</td>
<td><img src="image" alt="Balloon" /></td>
</tr>
<tr>
<td>66</td>
<td>3</td>
<td>4</td>
<td>3x</td>
<td><img src="image" alt="Balloon" /></td>
</tr>
<tr>
<td>99</td>
<td>4</td>
<td>3</td>
<td>4x</td>
<td><img src="image" alt="Balloon" /></td>
</tr>
<tr>
<td>132</td>
<td>5</td>
<td>2.4</td>
<td>5x</td>
<td><img src="image" alt="Balloon" /></td>
</tr>
</tbody>
</table>
Enjoy the sea life!
Physics of Diving
Boyle’s Law

- Pressure and volume are inversely proportional

- With descent, volume in air cavity decreases (greater pressure at depth)

- With ascent, volume in air cavity increases (less pressure)

- If body air spaces can’t compensate for pressure changes get **BAROTRAUMA**
Henry’s Law

- At constant temperature, amount of gas dissolved in liquid is directly proportional to partial pressure of that gas.

- At sea level, tissue equilibrated with nitrogen.

- With descent, pressure increases, more nitrogen enters tissues.

- With ascent, pressure decreases, nitrogen leaves body. If can’t compensate = Decompression Sickness.
Dalton’s Law

- The total pressure of a gas mixture is equal to the sum of the partial pressures of the individual gases

- As the pressure increases at depth so does the partial pressure of each gas

- Air at sea level is 21% oxygen and 79% nitrogen

- Can lead to **Oxygen Toxicity** and **Nitrogen Narcosis**
Charles’ Law

- At constant pressure, the volume of gas varies directly with absolute temperature.
- Volume in tank decreases when temperature is lower so less air available to diver.
- Volume increases with higher temperatures.
- Can lead to out of air and drowning or over-expansion of tank and explosion.
watch your gauges!
Non-profit medical and research organization dedicated to safety and health of recreational scuba divers

Duke University Medical Center

24 hour Emergency Hotline
- 1-919-684-8111
- 1-800-446-2671
DECOMPRESSION SICKNESS—“The Bends”

- If ascent too rapid, nitrogen bubbles form in tissues and cause decompression sickness.

- Nitrogen bubbles expand in vascular spaces causing pain, lymphatic occlusion, ischemia and infarction.

- Symptom onset usually within a few hours, 90% within 12 hours of surfacing.
TYPES OF DECOMPRESSION SICKNESS

- DCS Type 1 - unilateral joint pain or transient skin itching and mild rashes, lymphatic obstruction with edema

- DCS Type 2 - more serious, neurologic (most common), pulmonary and cardiac symptoms
  - Patchy paresthesias, constricting sensation around abdomen or thorax, extreme fatigue, slow mentation, ataxia, paralysis, urinary retention, blindness or coma
Arterial Gas Embolism

- Most feared complication from too rapid an ascent
- Usually occurs during a panicked ascent when divers hold their breath
- Air is trapped in lungs resulting in pulmonary over inflation and alveolar rupture
- 90% symptoms occur within 10 minutes of surfacing
Percent Change in Lung Volume for 10 foot Changes in Depth

- 32.7% Surface
- 19.2% 20
- 12.7% 40
- 9.0% 20
- 6.7% 40
- 5.2% 60
- 4.1% 60
- 3.4% 80
- 2.8% 80
- 2.4% 100
- 2.0% 100
Initial Management of DCS and AGE

- 100% oxygen most important while diver is on the way to the recompression chamber

- O2 reduces bubble size of inert gas and speeds washout

- Prevents hypoxia and bubble interaction with blood vessel lining
  - Capillary leak, bleeding, inflammation, ischemia, cell death
Call 911!
Recompression chamber at 60 fsw (2.8 ATA) and with 100% O2 by face mask for 2-5 hours each session, until symptoms abate

- Compression of bubbles to a smaller size or back in solution
- Enhance nitrogen release from tissues by breathing pure oxygen
- O2 for marginally ischemic tissues

Hydration oral or IV

? NSAIDS/ASA – anti-platelet effect, no consensus

Steroids probably not helpful

NO Trendelenburg, supine position
Recompression Chamber
Definitive treatment for AGE and DCS
watch your depth!
Intoxication experienced by divers breathing compressed air at increasing depths and increasing partial pressures of nitrogen

Symptoms develop between 70-100 feet and increase with increasing depth

Resolves with ascent to shallower depths
Carbon monoxide poisoning - as pressure increases, partial pressure of gases in breathing mix increase. Small amount CO in tank on surface, can be significant at depth

Oil-lipoid pneumonitis
Elevated partial pressures of oxygen also dangerous

CNS toxicity especially with newer gas mixes “nitrox” up to 36% oxygen

Get higher partial pressures of oxygen with increased depth

Visual disturbances, ear problems, nausea, twitching, irritability, dizziness, convulsions
Come back soon!

Thanks to Diann Laing for technical and artistic assistance.
Photos Courtesy of:
Dr. Claudia Christman
Gerard and Vicky Newman
Dive Tek Adventures

Kona, Hawaii
Diver’s Alert Network - DAN  
www.diversalertnetwork.org  
1-919-684-4326

Diving Medicine Online  www.scuba-doc.com

Undersea and Hyperbaric Medicine Society UHMS  www.uhms.org

Scubamed  http://www.scubamed.com/