Deep: Scuba diving associated Risks and Complications
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Objectives
• Know fitness for diving
• Know aspects and clinical symptoms of Barotrauma
• Know clinical presentation of POIS
• Know clinical presentations of Decompression Sickness (DCS)
• Miscellaneous: Malaria, Altitude etc.

Introduction
• 1-3 Million scuba divers in USA
• ~$500 Million/year industry in USA
• 1 million scuba divers in EU
• 3-9/100,000 deaths in US alone (60% Drowning)
• Tropical destinations common

Case
• A 45 y/o lawyer presents to your office for pre-travel visit. He is going to Bonaire in the Caribbean. In addition to food and water hygiene counseling and Hep A vaccine he asks you to complete his Scuba physical exam form, he has a history of patent foramen ovale.
• A: fill out the form
• B: charge extra and fill out the form
• C: refer to a diving medicine physician
**Fitness to dive**

- Should be done by a certified diving physician
- Age, Sex, Training
- Contraindications: Absolute (Seizures, Active cardiac disease, active psychiatric disease, SCD, Chronic lung diseases, perforated TM, hernias, orthopedic injury)
- Contraindications: Relative (Asthma, DMII, Migraines, recent eye surgery, URI, pregnancy)
- PFO controversial: 20% of population; 40% DCS cases

**Medications**

- Contraindicated:
  - Narcotics, antipsychotics, Anti-convulsants
  - Beta blockers or vasodilators if recently started
- Relatively safe
  - NSAIDS, acetaminophen, Digoxin, Antibiotics, decongestants, antihistamines, scopolamine, meclizine

**BAROTRAUMA**

- Injury caused by changes in pressure
- Boyle's Law (Pressure inversely proportional to Volume P=1/V)
- “Ingredients”
  - rigid walls
  - gas filled space
  - enclosed space
  - ambient pressure change
- 100% Preventable by not diving when abnormal anatomical conditions exist

**BAROTRAUMA**

- SQUEEZE
- barotrauma of descent
- 10m=1 ATM
- damage from relative vacuum

A 28 y/o female presents to your office after returning from Sulawesi Indonesia. She had a bad URI but traveled anyway, she went diving since she had invested so much in trip. After one dive she felt pressure in her L ear then a loud noise and felt slightly dizzy. Now “it sounds like I’m under a pillow when people talk” she stopped diving for the last 2 days.

- This is
- A: Barotrauma sinus squeeze
- B: BarotraumaTM rupture
- C: Barotrauma Oval window rupture
- D: DCS (The bends)
- E: Arterial Gas Embolism
BAROTRAUMA

• REVERSE SQUEEZE
  - barotrauma of ascent
  - damage from expanding gases

• EXTERNAL EAR
  - Predisposing Factors
    • obstruction of the external canal by wax
    • tight wet suit hood
    • ear plugs
    • otitis externa
  - Usually leads to reverse squeeze

BAROTRAUMA

• MIDDLE EAR “MOST COMMON”
  - Etiology: blocked Eustachian tube
  - Predisposing Factors
    • infections (URI)
    • allergies (Hay Fever)
    • anatomic variations
    • inability to equalize pressure
  - Usually leads to ear squeeze

BAROTRAUMA

• EAR SQUEEZE
  - Clinical Manifestations:
    • mild: injected TM
    • moderate: intratympanic hemorrhage
    • severe: hemorrhage behind TM with or w/o perforation
  - If perforation occur, rush of cold water into inner ear can cause vestibular symptoms (caloric vertigo) and ultimately infection

BAROTRAUMA

• CLINICAL MANAGEMENT
  - Treatment
    • no diving until re-evaluated
    • decongestants i.e. Sudafed, Afrin
    • If perforated consider ENT referral
BAROTRAUMA

• INNER EAR
  - implosive or explosive injury
  - round window rupture
  - oval window rupture
  - intracochlear membrane rupture

CASE

A 20 year old female on their 3rd dive descends rapidly to 15 meters. She had trouble Valsalva-ing on descent and experienced stabbing pain in the forehead for 30 sec before clearing her ears, on arrival at surface she took off her mask and had profuse epistaxis.

This is:
A: Barotrauma ear squeeze
B: Type I DCS (the bends)
C: Barotrauma sinus squeeze
D: Arterial Gas Embolism

BAROTRAUMA

• INNER EAR INJURY
  - Clinical Manifestations
  - fullness of middle ear on descent
  - forceful Valsalva or severe ear squeeze
  - audible “pop”
  - sudden onset of roaring tinnitus
  - sudden onset of vertigo
  - persistent increasing vertigo
  - persistent neurosensory hearing loss
  - visual findings (nystagmus)

TREATMENT

• R/O Air Gas Embolism or Decompression Sickness
• strict bed rest
• avoid straining (stool softeners, antiemetics, antivertigo medications, sedation)
• ENT REFERRAL: standard of care is surgery within 24 hours

BAROTRAUMA

• SINUS
  - obstructed sinus ostium (infection, allergy, anatomy)
  - Pain and bleeding after squeeze or reverse sq.
  - NO diving
  - decongestants
  - observe for infection

TOOTH

• Prevention is the key!
• Pain in tooth on ascent
• Predisposing Factors
  - dental disease
  - inadequate dental restorations
  - recent dental work

BAROTRAUMA

• INNER EAR INJURY
  - Clinical Manifestations
  - fullness of middle ear on descent
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BAROTRAUMA

• FACE MASK SQUEEZE
  - failure to clear face mask on descent
  - subconjunctival hemorrhages
  - no treatment necessary

Lester Quayle and Rita Barton, Duke University

BAROTRAUMA

• ABDOMINAL SQUEEZE
  - usually from panic ascent
  - antacid use
  - overbreathing and air swallowing
  - symptoms abate with descent

BAROTRAUMA

• PULMONARY
  - Squeeze
    • deep breath-hold dive to a depth at which lung volume is reduced below residual volume
  - Over expansion
    • intra alveolar hemorrhage, exudate
    • chest pain
    • progressive dyspnea
    • progressive frothy, bloody sputum
  - Can be accompanied by AGE and DCS

Case

• A 23 y/o male is diving for the 4th time ever at 10 meters, he sees a rock lobster and panics. He swims as fast as he can to the surface while holding his breath, on the surface he has aphasia, an weakness in his LUE of handgrip and wrist flexion.
• This is:
  • Type II DCS (the bends)
  • Arterial Gas Embolism
  • Pulmonary Squeeze
  • Round window rupture

PULMONARY OVERINFLATION SYNDROMES (POIS)

• MEDIASTINAL EMPHYSEMA
  - results when gas expansion forces gas into the loose mediastinal tissues in the middle of the chest
  - symptoms: chest pain behind the sternum (tightness, burning)
  - no other symptoms
  - symptoms generally do not get worse
  - no treatment is necessary
  - O\textsubscript{2} may reduce symptoms faster
PULMONARY OVERINFLATION SYNDROMES (POIS)

• SUBCUTANEOUS EMPHYSEMA
  - results from expansion of gas which has leaked from the mediastinum into the subcutaneous tissues of the neck
  - symptoms: feels like “Rice Krispies” under the skin
  - there may be a voice change due to pressure on the larynx
  - no treatment is necessary
  - O₂ may reduce symptoms faster

• PNEUMOTHORAX
  - accumulation of gas within the pleural space
  - symptoms: chest pain, more likely lateral or apical; cough; SOB
  - Treatment: 100% O₂ and chest tube prn

• ARTERIAL GAS EMBOLISM
  - THE MOST SERIOUS POTENTIAL COMPLICATION OF DIVING CAUSED BY EXCESS AIR PRESSURE IN THE CHEST!!
  - alveolar rupture with injection of air into capillary so that a bolus (bubble) of air enters pulmonary veins and left ventricle
  - Occurs suddenly, usually after a rapid ascent

Arterial Gas embolism

• Presents as embolic stroke
  - A DETAILED neuro exam is critical
• Majority in MCA distribution
  - Aphasia
  - Apraxia
  - Hemiparesis
  - Hemisensory loss
• Minority Vertebral Basilar
  - Visual or cerebellar deficits

• ARTERIAL GAS EMBOLISM
  - the brain is the most significant site of embolus
  - symptoms: ANY type of neurologic sign or symptom (unconsciousness, weakness, paralysis, paraesthesia, etc) within 10 min of surfacing
  - AGES do not go to the spine (think DCS)
  - tx: O₂ & IMMEDIATE RECOMPRESSION
Decompression sickness (DCS)

- Inert Gas (N₂) saturated in tissue on dive
- As diver ascends gas comes out of solution
- Gas forms bubbles-causes vascular obstruction, ischemia, cell death
- Bubbles activate clotting system, cause plt clumping etc. also activate cytokines
- Onset of sx is delayed unlike AGE

Decompression Sickness (DCS)

- Risk factors
  - Obesity
  - Age
  - Injuries
  - Excessive exercise
  - Dehydration

- Mitigators
  - Being physically fit reduces risk of Decompression Sickness (DCS)

Decompression sickness (DCS)- Classification

- Type I
  - PMS-Pain, Marbling, Swelling
    - “Cutis marmarata”
    - Bone/joint pain
    - Not life threatening

- Type II
  - Serious neurological symptoms
    - Cerebral, Spinal cord, Pulmonary, Inner ear

- Spinal
  - Usually sensory level, lower motor neuron sx, bowel bladder dysfunction

- Cerebral
  - Fatigue, upper motor neuron sx,

- Pulmonary (chokes)
  - Cough, chest pain

- Inner ear (staggers)
  - Vertigo, N&V, tinnitus, hearing loss
  - Most common with Heliox diving
Treatment

• Type I
  - Can be managed with Non Steroidal Anti-Inflammatory Drugs and observation if remote from a chamber
  - Hydration
  - USN Treatment Table 5
• Type II
  - Needs emergent recompression, USN TT6 or higher
  - IV hydration and Oxygen is paramount
  - Medevac is by pressurized jet (3000 feet max)

Nitrogen Narcosis

• Rapture of the Deep
  - Generally > 100 fsw
  - Martin's Law
  - Loosened inhibitions
  - Agitation
  - Tunnel Vision
  - Tinnitus/Rushing Sound
  - Poor Judgement
  - Simple Tasks Become Difficult
  - LOC
  - Resolves with ascent or He

Hypoxia/ Hyperoxia

• Issue with Nitrox Diving and Rebreathers
• Hypoxia
  - Similar to Narcosis
• Hyperoxia
  - VENT ID-C
    • Visual
    • Ear
    • Nausea/Vomiting
    • Twitching/tingling
    • Irritability
    • Dizziness
    • Convulsions

Carbon Dioxide/ Monoxide Poisoning

• Usually from bad air source
  - Compressor intakes near exhausts
• CO₂ also from over-breathing equipment
  - Hyperventilation
  - CO₂ Scrubber Failure (Rebreathers)
• Increased RR
• Irritability
• Sweating/N/V
• Drowsiness
• HA
• Difficulty
• Concentrating
• Seizures (CO₂)
• LOC

Malaria and Diving

• Mosquitoes can fly 2 miles offshore
  - Both live-aboard boats and shore facilities at risk
• Medications are Completely Unstudied
  - Mefloquine-like unsafe Study in Swiss Aircraft pilots found tolerated well but neuro sx and seizure risk
  - Doxycycline
    • May have GI side effects (mimic Abd squeeze, DCS)
    • Photosensitivity(marine environment)
  - Primaquine-no data
    • GI side effects(see above), maybe less effective agent
  - Atovaquone/Proguanil-My personal preference
  • No data on safety, recommended by military aviation community

Altitude and Diving

- Ascent from sea level mimics conditions of ascent from dive
  - Adds DCS risk if recently dove
- Do NOT fly for 24h after diving (cabin is 8000 foot equivalent, rapid ascent)
- Ascending to altitude after diving
  - Table 9-6 provides guidance on surface time required before climbing
  - Only for climbs of 10K feet or less
- Diving at altitude
  - Special tables and adjustments are required

Summary

- Pulmonary overinflation runs from common (ear squeeze) to deadly (AGE)
- Not diving while ill markedly reduces chances for POIS
- Symptoms are usually immediate on dive or ascent and immediately after surfacing
- Decompression sickness runs from pain, to life threatening

Resources

- Divers Alert Network emergency hotline
  - +1-919-684-9111
- DAN Medical Information Line
  - +1-919-684-2948
  - http://www.diversalertnetwork.org/medical/faq/

Questions?

- kpetersen@peacecorps.gov

Summary

- DCS is best prevented by adequate hydration, and fitness as well as adherence to dive tables and computer algorithms
- DCS usually needs recompression as soon as possible
- O₂ and IVF are helpful in stabilizing patient until they can get to a chamber