Diving Emergencies
The First 24 Hours

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Dive Emergencies – the First 24

Background

Descent / Ascent Injuries

The first 10-15 Minutes

The First 24 Hours

The ER experience

Hyperbaric Medicine

DAN® Divers Alert Network (DAN) 2008 Annual Report

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- Largely based on 2006 events
- Project Dive Exploration (PDE)
- Dive injuries
- Dive fatalities
- Breath-hold incidents.

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RUBICON FOUNDATION

- http://archive.rubicon-foundation.org

RUBICON FOUNDATION Research Repository

Table 1: Occurrence of Sports Injuries for 1996
Source: Accident Facts, 1998 Edition (detailing 1996 data), National Safety Council.

Incidence of Nonfatal Diving Injuries

Sport	Number of Participants	Reported Injuries	Incident Index
Bicycling	71,900,000	566,676	.788
Swimming	60,200,000	93,206	.154
Fishing	45,600,000	76,828	.168
Roller skating	40,600,000	162,307	.399
Golf	23,100,000	36,480	.158
Tennis	11,500,000	23,550	.204
Water skiing	7,400,000	9,854	.133
Scuba	1,000,000	935	.094

Table 1: Occurrence of Sports Injuries for 1996
Source: Accident Facts, 1998 Edition (detailing 1996 data), National Safety Council.

DIVING FATALITIES

- SCUBA Diving .003-.005%
- Rock climbing .034%

Around 100 SCUBA diving deaths per year

Diver Physiology

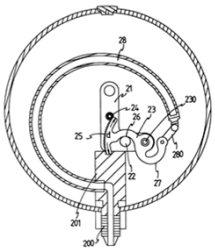
- Pressure
- Effects of pressure
- Gas absorption

What is pressure?

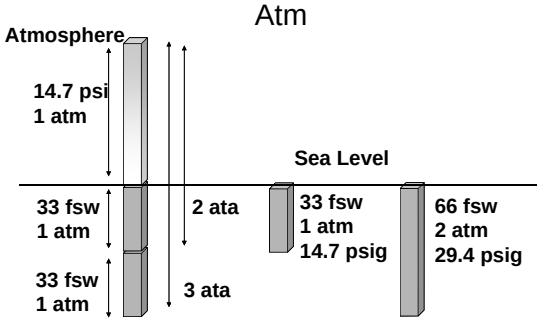
1 Atmosphere = 14.7 psi = 760 mmHg = 33 fsw = 10 msw = 34 ffw = 1.03 kg/cm^2 = 1.01 bar = 101 kPa

ATA = Atmospheres Absolute (psia)

Atm = Atmospheres Gauge (psig)

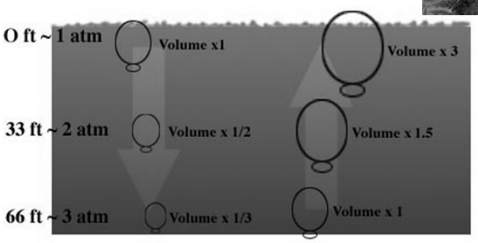


Absolute Pressure = Gauge Pressure + 1 Atm



Pressure / Volume

- Mechanical Effects of Pressure
  - Robert Boyle

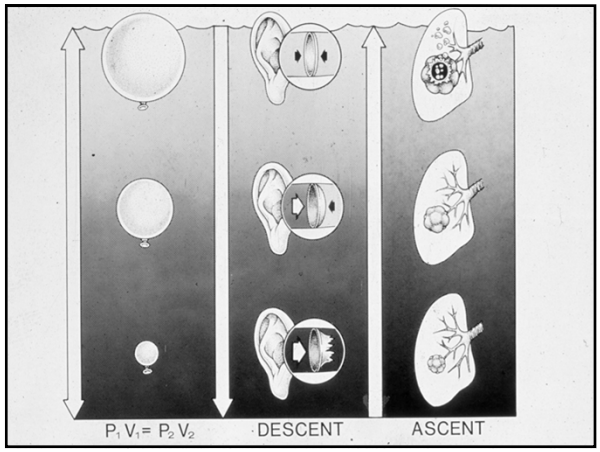


Dissolving Gas

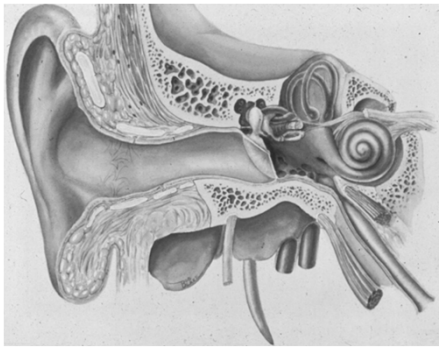
- *Henry's Law:* amount of gas (nitrogen, oxygen, etc.) dissolved in the body increases as surrounding total pressure increases
- Over time reaches state of equilibrium
- May become "supersaturated"

DIVING MEDICINE

- The first 10-15 Minutes
  - Barotrauma
    - mask, sinuses, ear, suit, dental
    - Pulmonary Injury
    - Arterial Gas Embolism (AGE)
- The First 24 Hours
  - Decompression Sickness (DCS)
    - DCS Type 1
    - DCS Type II
    - combined AGE and DCS
    - Pulmonary Chokes
    - Vestibular DCS
  - Strains/Overuse



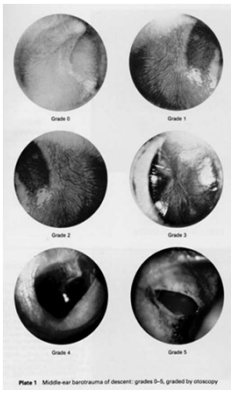
EAR BAROTRAUMA



EAR BAROTRAUMA

- Clinical Presentation
  - Fullness and pain
  - Mild tinnitus
  - +/- vertigo
    - nausea, vomiting, vertigo, disorientation
  - Hearing loss
  - With TM rupture
    - Pain often relieved
    - Cold caloric stimulation → vertigo, nausea, vomiting

- TEED SYSTEM
- Middle Ear Barotrauma



EAR BAROTRAUMA

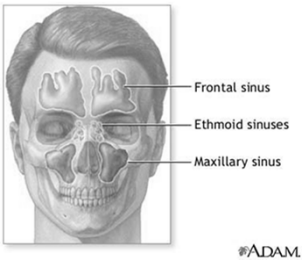
- Treatment
  - Decongestants
  - Analgesics
  - No pressure changes for 7-14 days
  - Inner Ear - avoid increased CSF pressure
    - valsalva, straining, lifting, coughing
  - avoid loud noises

MASK BAROTRAUMA

- Clinical
  - Periorbital/facial edema
  - Purpuric hemorrhages
  - Conjunctival hemorrhages
- Treatment
  - Symptomatic
  - Cold compresses
  - Analgesics

SINUS BAROTRAUMA

- Inadequate Pressure Equalization
- Causes
  - Thickened tissue (cold)
  - Extra tissue
  - Masses



SINUS BAROTRAUMA

- Clinical Presentation
  - Pain
  - Frontal sinus most common
  - Epistaxis
  - Pain
  - Paresthesias

SINUS BAROTRAUMA

- Treatment
  - Decongestants
  - Analgesics
  - ?Antibiotics? for secondary infection
  - Surgical drainage if indicated (rare)
  - No atmospheric changes for 7-14 days

BAROTRAUMA OF ASCENT

- Ear and Sinus
  - similar to barotrauma of descent
- Alternobaric Vertigo
  - Unilateral increase in middle ear pressure
  - unequal vestibular stimulation
  - vertigo, nystagmus, vomiting
  - symptoms short duration

OTHER BAROTRAUMA

- External Ear Canal
- Skin
- Dental

Gastrointestinal Barotrauma

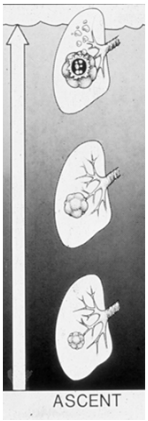
- Swallowed air
- Abdominal pain, belching, flatus
- Novice divers that swallow air, carbonated beverages, eating heavily before diving

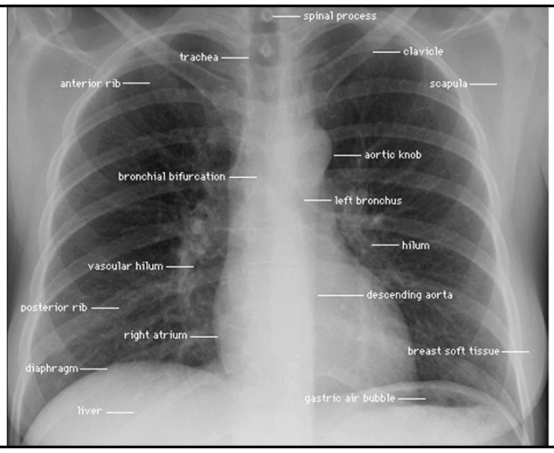
PULMNARY BAROTRAUMA

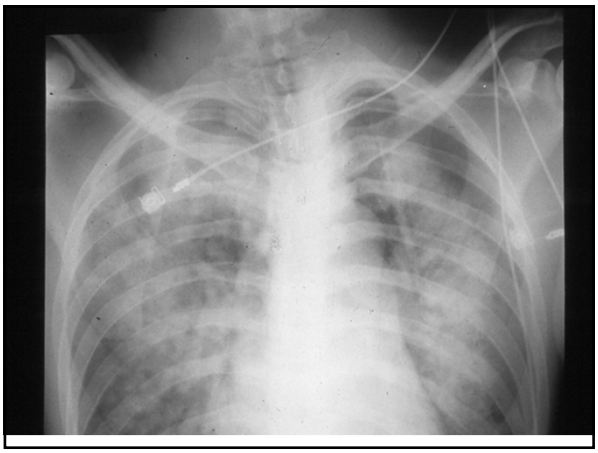
- Local lung injury
- Mediastinal
- Subcutaneous
- Pneumothorax
- Arterial gas embolism

Pulmonary Barotrauma

- Etiology
  - Running out of air supply
  - Dropping weight belt
  - Uncontrolled buoyancy
  - Panic and breath-holding ascent
  - Preexisting blebs or bulla
  - Gas trapping

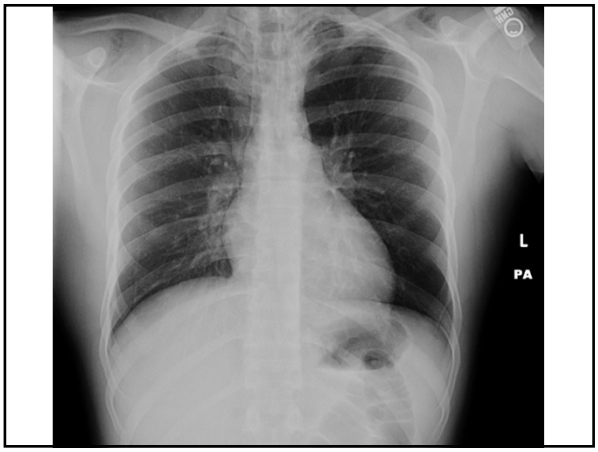


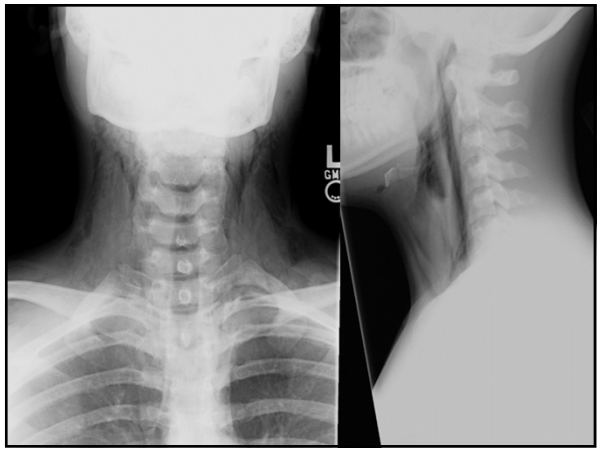




Direct Pulmonary Damage

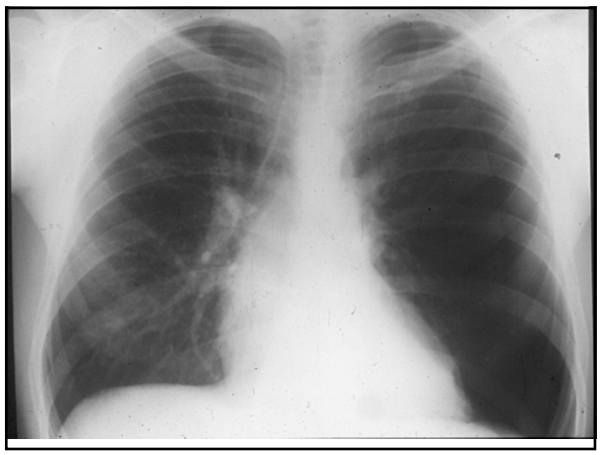
- Shortness of breath
- Chest pain
- Hypoxia
- Possible hemoptysis
- Decreased breath sounds





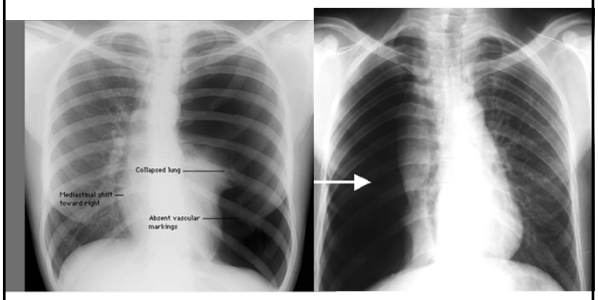
Pneumomediastinum
Subcutaneous Emphysema

- Most common manifestation
- Chest pain, shortness of breath, hoarseness and dysphonia
- Subcutaneous air “Rice Crispy Skin”
- Detailed neurologic exam for AGE
- Rx. Observation, 100% oxygen, rest



Pneumothorax

- Rare: <10% of pulmonary barotrauma
- Pleuritic chest pain, dyspnea
- Unilateral decreased breath sounds
- RX:
  - 100% oxygen, observe, repeat CXR
  - Tube thoracostomy (chest tube)
  - May need needle thoracostomy in field



Types of Gas Embolism

- Venous Gas Embolism (VGE)
- Arterial Gas Embolism (AGE)

Venous Gas Embolism (VGE)

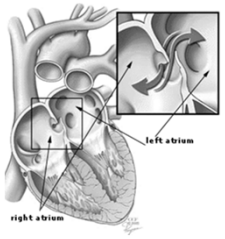
- Causes
  - Diving, neurosurgical procedures, central venous catheterization, trauma, high-pressure mechanical ventilation, Thoracocentesis, Hemodialysis, invasive vascular procedures, Laparoscopic procedures (CO_2)

Venous Gas Embolism (VGE)

- How much is too much?
  - Traditionally 3-5ml/kg
  - In some cases 10-20ml
  - 2-3ml in the cerebral system is fatal
  - 0.5ml in the LAD causes V-Fib

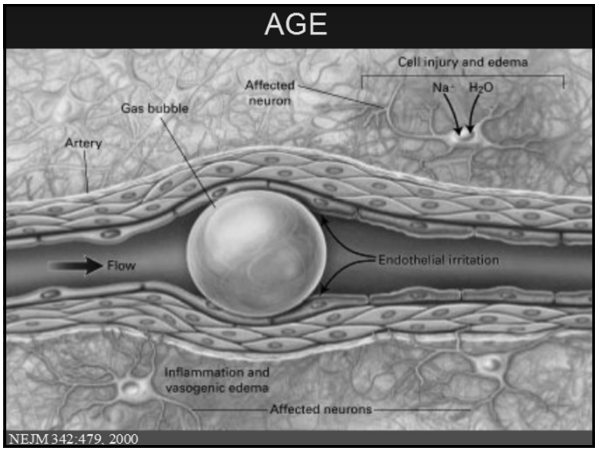
Venous Gas Embolism (VGE)

- Venous to arterial gas shunting
  - ≈30% PFO incidence in the general population
  - Leads to arterializations of venous gas bubbles.



Venous Gas Embolism (VGE)

- Treatment
  - Supportive
  - Oxygen
  - HBO usually not warranted in mild cases.

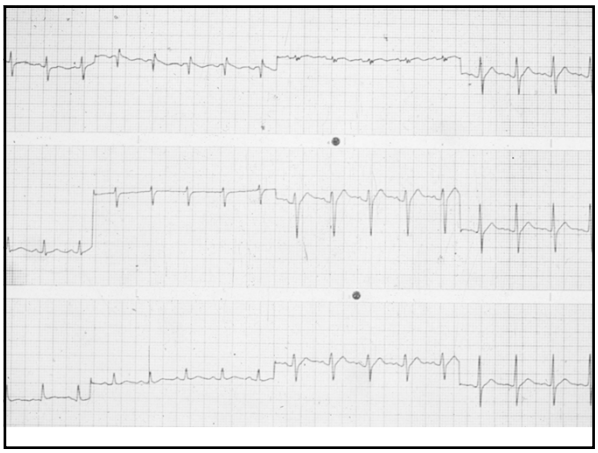


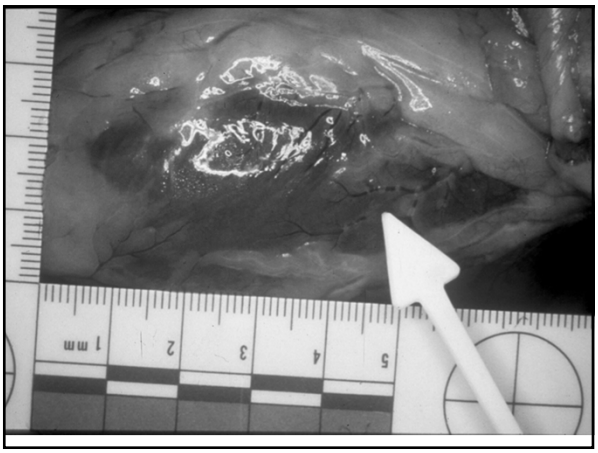
Arterial Gas Embolism (AGE)

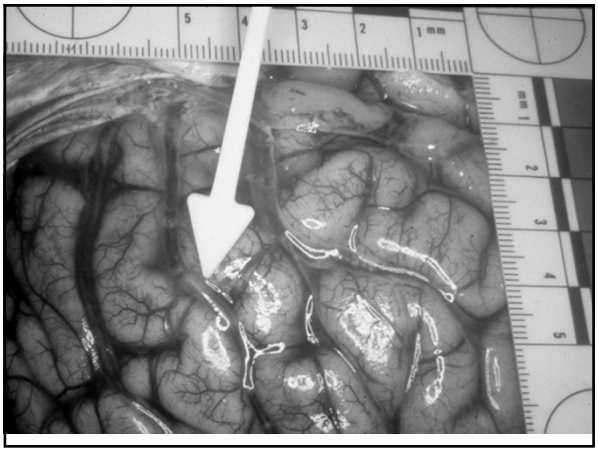
- Signs and symptoms
  - Depends on amount and location of gas
  - LOC, stupor, confusion, headache, cortical blindness, monoplegia, hemipalegia, focal paralysis, paresthesias, sensory disturbances, convulsions, aphasia, visual field defects, vertigo, dizziness are frequent findings
  - Sudden Death (5%)

Arterial Gas Embolism (AGE)

- Diagnosis
  - Onset within short duration of ascent (10-15 minutes)
  - Clinical suspicion
  - CXR
  - CT head
  - MRI?, Labs?
  - May be a delayed diagnosis because of not considering it.

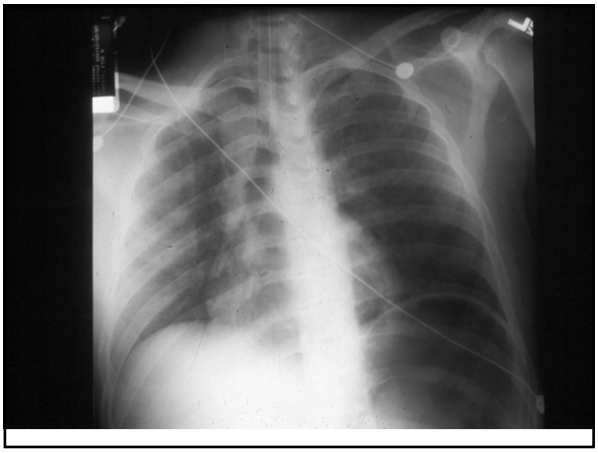


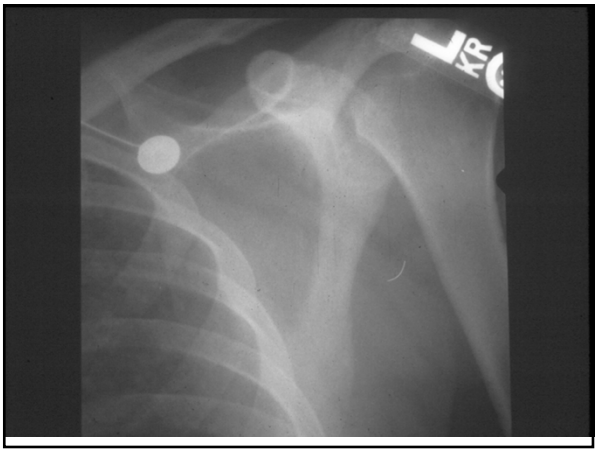


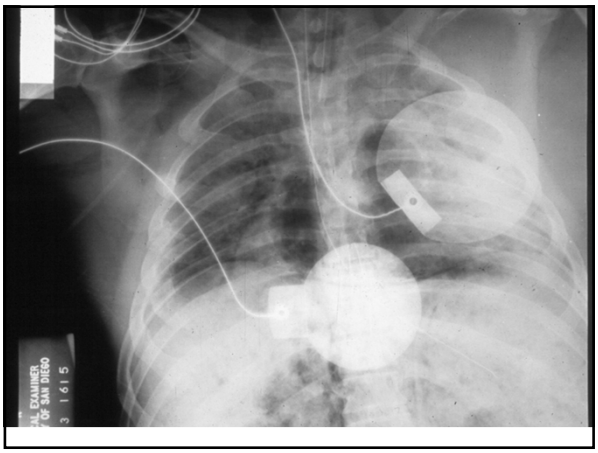


Arterial Gas Embolism (AGE) Gas Lock

- With high volumes of gas, a gas-lock may occur in the left ventricle leading to cardiovascular collapse.





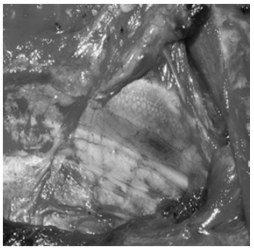


Arterial Gas Embolism (AGE)

- Treatment
  - Supportive Care
  - High flow oxygen
  - Hyperbaric Oxygen Therapy
  - Fluids

Arterial Gas Embolism (AGE) Hyperbaric Oxygen Treatment

- Rationale
  - Reduces bubble size
  - Increases diffusion gradient of embolized gas
  - Oxygenates hypoxemic tissues
  - Reduces cerebral edema



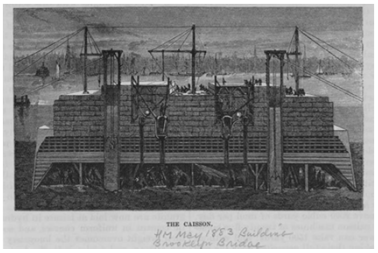
- Treatment Protocol
  - USN TT 6 (TT6A)
  - Hart TT (monoplace chamber)

DIVING MEDICINE

- The First 24 Hours
  - Decompression Sickness (DCS)
    - DCS Type 1
    - DCS Type II
    - combined AGE and DCS
    - Pulmonary Chokes
    - Vestibular DCS
    - *"Decompression Illness - DCI"*

Decompression Sickness

- Grecian Bend



- Brooklyn Bridge – Caisson
  Dr. Andrew Smith

Signs and Symptoms of DCS

- Depend on ultimate location of bubbles
  - Bubbles preferentially form around joints and in spinal cord venous plexus
- Occurs usually within 3 hours of surfacing
  - May delayed up to 6-12 hours
  - rare to present 24 hours after diving (unless altitude exposure)

Decompression Sickness

- DCS Type I
  - Pain, fatigue, Skin and lymphatic bends
- DCS Type II
  - Neurologic or spinal cord
- Pulmonary DCS “chokes”
- Vestibular DCS
- DCS Type III

DCS - *Time to onset of symptoms*

PERCENT CASES	TIME TO ONSET
50	< 30 minutes of surfacing
85	< 1 hour of surfacing
95	< 3 hours of surfacing
1	delayed > 6 hours

DCS - *Sport Divers*

SYMPTOMS	FREQUENCY
joint pain	50%
neurologic symptoms	50%

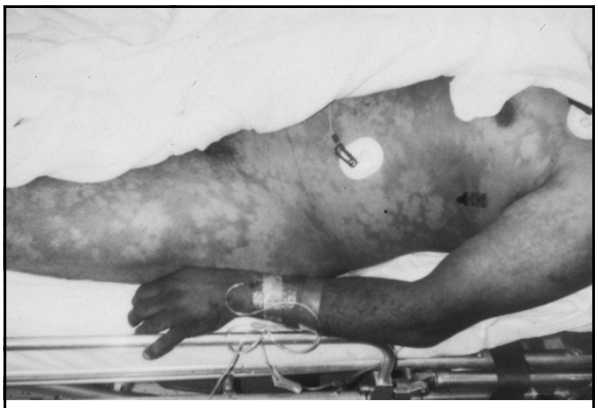
Musculoskeletal DCS (the bends)

- Joint pain
- Shoulders and elbows
- Fatigue
- Dysbaric osteonecrosis

Skin Manifestations of DCS: “Skin Bends”

Cutaneous DCS – Cutis marmorata

- Pruritus, erythema, heat sensation
- Short lived
- Differentiate from sun reactions, marine envenomations
- Cutis marmorata
  - Blotchy, marbled lesions



Neurologic DCS

- Spinal cord and peripheral nerve symptoms predominate
- Paresthesias
- Weakness
- Urinary retention
- Cerebral dysfunction

Pulmonary DCS (the chokes)

- Venous gas emboli
- Cough, chest pain, dyspnea
- Tachycardia, tachypnea, shock
- Pulmonary edema

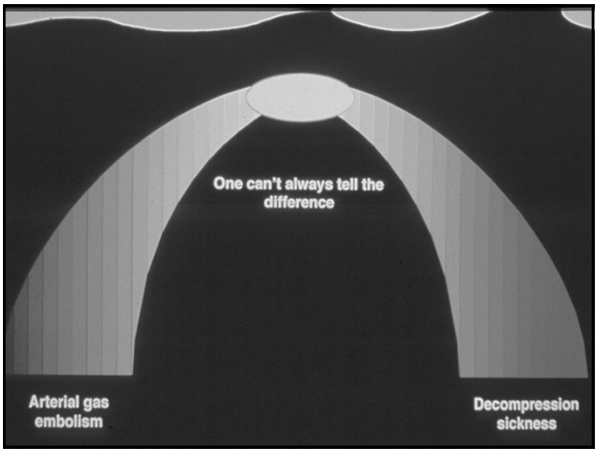
Differentiation of Inner Ear Barotrauma from Inner Ear DCS

Inner ear barotrauma	Initial descent Hx of difficulty equalizing middle ear pressure Hx of forceful valsalva Physical finding of middle ear barotrauma
Inner ear DCS	Significant time and depth underwater

- Treatment of inner ear DCS is HBO
- Inner ear barotrauma may be worsened by HBO

AGE vs DCS ?

Factors	AGE	DCS
Diving profile	ascent (rapid, breath-holding)	time/depth profile (minimum exposure)
Symptom onset	0-10 minutes	minutes-hours
Type of symptoms	pulmonary cerebral neurologic	joint pain spinal cord



DECOMPRESSION ILLNESS - DCI

- AGE & DCS
  - different initiating event with similar clinical presentation
  - "Type III DCS"
  - AGE precipitates DCS
  - DCS precipitates AGE

Prehospital Care

- Airway, Breathing, Circulation
- Position
- Oxygen
- Fluids
- Secure gear / Buddy
- Transport

Transport and the Emergency Room

- IV fluids
- Oxygen
- Monitor
- Watch for changing neurologic deficits
- Obtain as complete a story / info as possible.

Transport and the Emergency Room

- EKG
- Xray, CT
- Labs as needed (CPK for DCS)
- Rule out other causes ie: Cardiac
- Early consult with DAN / Hyperbaric facility

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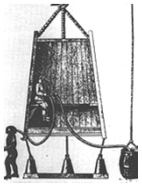
Hyperbarics - History

- Spawned from Diving History
  - Breath Hold
  - Heavy Vessel
    - 1500's Diving Bell
    - 1870's Caissons
  - Helmet
    - 1823 Deane's Smoke Helmet
  - SCUBA
    - 1943, Frenchmen, Emile Gagnan and Jacques Cousteau



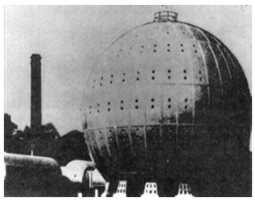
Hyperbarics - History

- 1662 Henshaw - the "Domocilium"
- 1670 Boyle Describes DCS in snake

- 1775 - Priestly discovers Oxygen
- 1879 - Fontaine built a mobile hyperbaric surgical chamber

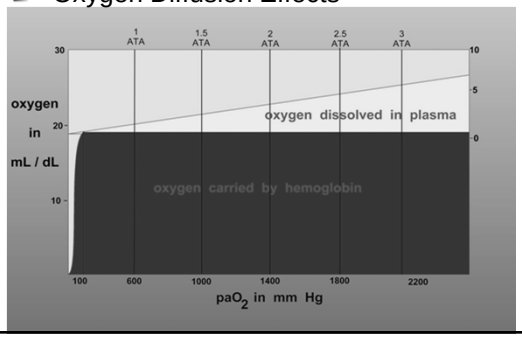
Hyperbarics - History

- 1928 "Steel Ball Hospital" Dr. Cunningham
- 1930's Behnke:
  - narcotic effect of nitrogen
  - O2 for the tx of DCS
- 1940's US Navy publishes treatment table



Hyperbaric Medicine How it Works

- Oxygen Diffusion Effects



Adverse Effects of HBO

- Middle Ear / Sinus Barotrauma
- **Pulmonary Barotrauma**
- **Arterial Gas Embolism**
- CNS Oxygen Toxicity
- Pulmonary Oxygen Toxicity
- Visual Refractive Changes

Hyperbarics - Contraindications

- *Absolute*
  - Untreated pneumothorax
  - Certain meds
    - Doxorubicin, bleomycin, disulfiram, cis-platinum, sulfamylon
  - Dead patients

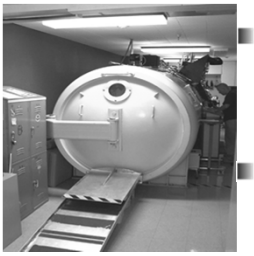
Hyperbarics - Contraindications

- *Relative*
  - Inability to equalize ears or sinuses
    - URI, OM, sinusitis, eustachian tube dysfunction
  - Emphysema with CO_2 retention
  - Seizure Disorder
  - Pregnancy
    - NOT contraindicated in an emergency
  - Claustrophobia

Chambers



UCSD Hyperbaric Chamber



- **UCSD Hyperbaric Medicine Dept. 619-543-6400**
- **Diving Clinic 619-471-9210**

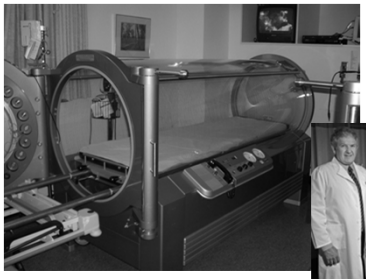
Catalina Hyperbaric Chamber - USC



- **24 Hour Emergency Line**
  310-510-1053

Long Beach Memorial

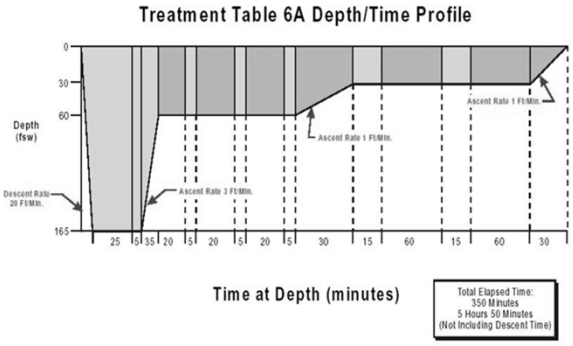
(562) 933-6960

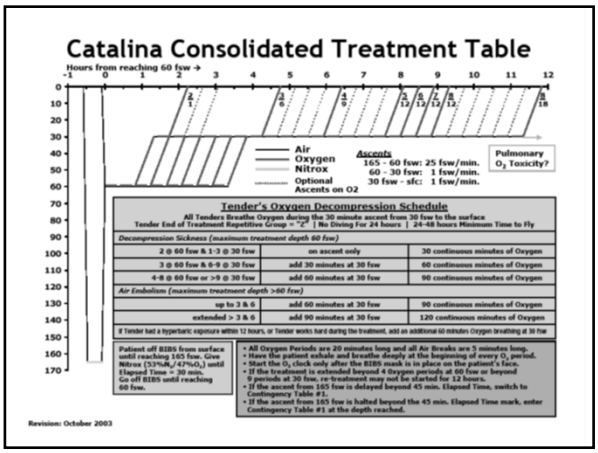



USN Treatment Tables

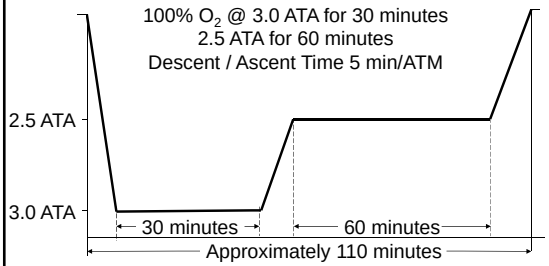
- USN Table 4
- USN Table 5
- **USN Table 6**
- **USN Table 6A**
- USN Table 7


USN Treatment Table 6A

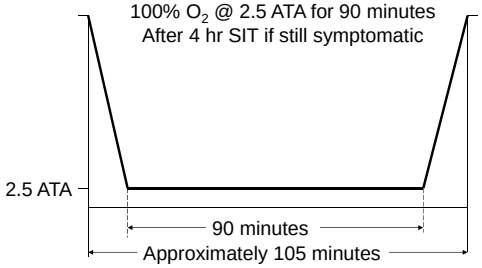




Hart AGE/DCS Monoplace Treatment Table



Hart AGE/DCS Repeat Monoplace Treatment Table



What to do when help is not near?

- To transfer or not?
- How long until transport?
- How far to transport?
- Risk vs Benefits.
- Do the symptoms warrant the transfer?