DECOMPRESSION SICKNESS (DCS) AT ALTITUDE
AOCOPM
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DANIEL J CALLAN, DO/MPH-TM
FAOCOPM, FASMA, FACOFP

SYLLABUS
1. HISTORICAL PERSPECTIVE
2. EPIDEMIOLOGY
3. BASIC PHYSIOLOGY REVIEW
4. HISTORY
5. PHYSICAL FINDINGS
6. DIFFERENTIAL DIAGNOSIS
7. TREATMENT AND REFERRAL

GOALS & OBJECTIVES
• At the end of this instructional period, the attendee should be able to:
  – understand the Historical lineage of bubble disease
  – Population based risk factors for developing DCS in an inhospitable environment
  – Take a pertinent history and perform a reproducible physical examination
  – Make a reasoned differential diagnosis
  – React in a timely fashion to appropriately provide safe treatment of DCS
BIOLOGICAL RISKS AT ALTITUDE

• LOSS OF ATMOSPHERIC PRESSURE DUE TO SUDDEN DECOMPRESSION
• EXPOSURE TO TOXINS
• MECHANICAL TRAUMA
• ACCELERATION AND DECELERATION FORCES
• EXTREME TEMPERATURES
• DEBRIS
• PSYCOLOGY
• ADVERSE BIOLOGICAL EFFECTS OF MICROGRAVITY
• RADIATION

WHAT IS ALTITUDE DCS/DSI

DEFINITION:
1. Dangerous & occasionally lethal medical condition (injury) caused by N2 bubbles that form in the blood & other body tissue resulting from a sudden environmental pressure change (decompression).
2. Refers to SYSTEMIC & LOCALIZED N2 BUBBLE injuries caused by rapid decrease in ATMOSPHERIC pressure, in either an air or water medium.
3. AKA: Decompression illness, generalized barotrauma or Caisson Disease, The Bends, Staggers, Chokes, Niggles, Dysbaric Osteonecrosis, Arterial Gas Embolism, Cutaneous and Lymphatic Bends, and THE GREAT IMITATOR.

WHAT IS DCS/DCI (Illness)

Epidemiology:

At Risk: particularly by environmentally exposed divers, aviators and astronauts (occasional passenger).

Occurs most commonly in scuba or deep-sea divers, although it also can occur during high-altitude or unpressurized air travel to aviators astronauts and passengers.

DCS is rare in pressurized intact and functional aircraft, such as those used for commercial flights without explosive sudden cabin decompression.

Incident rate of symptoms: skin changes (13%) & pain in muscles, joints, cramps (70%), numbness, nausea, paralysis, death (1-8%), and Pulmonary cough, dyspnea Chokes (3%).

EPIDEMIOLOGY OF DCS

• US Research material, indicate the Risk of DCS, in a maximum likelihood method, to 1,194 individuals exposed to high altitude, the corresponding DCS incidence rate (the average incidence rate of @ 33.6%).
• 7,872 calls or e-mails were logged into the Medical Services Call Center system by Divers Alert Network medics during the 2009 calendar year. The most common working diagnoses of the reported injuries were DCS and barotrauma (both at 26%), non-diving related (14%). DCS-like symptoms ranged from mild to severe, with many more cases being classified as possible rather than confirmed. Barotrauma most commonly involved the middle ear (50%), lungs (15%), and sinuses (14%).
• Statistics from one of the largest training agencies in the world, collected over a 10-year period, show an incident rate of only 0.472 fatalities per 100,000 dives.

HISTORICAL TRIP THROUGH TIME

• First written record of air as a quality was in 16th century BC Egyptian Ebers papyri: distinction made between good & bad air
• Homeric Greeks thought air was the conveyor of life Want of good air was called asma, and Bad air called miasma
• Thales of Miletus (7th century BC) observed water evaporated into air. Thought all life must be a mixture of water and air
• Aristotle disagreed and supported theory 5th century BC that divided all substances into fire, water, earth, and air.

• Anaximander (7th Century BC) called it to apeiron or substance which made up everything
• Leucippus & Democritus (5th century BC) developed the to apeiron into the atomic theory;
  — All things made up of indivisible units or atoms

Hippocrates developed this into the four humors:
• Yellow bile, black bile, phlegm, and blood
• Ruled medicine for the next 1000 yrs
• Opposing forces, which determined health & illness overtook atomic theory

Newton re-established the atomic concept
HISTORICAL TRIP THROUGH TIME

- 1650 Belgian Johan (Joan) Baptista van Helmont incinerated 60 lbs of coal within a 5 lb closed cylinder.
  - Vessel and ash still weighed 65
  - Thought he had freed solid matter into indefinable, invisible wild spirit that still had substance—spiritus sylvestre
  - Named this wild spirit, derived from a Greek word for chaos—gas
- Development of a vacuum was critical to understanding atmosphere
- The concept of “vacuum” was first proposed by the Greek, Democritus who thought an empty space must exist between atoms, which made up all things.

- 1820’s Jacques Charles & J.L Gay-Lussac independently recognized, that pressure or volume was related to temperature
  - \( \frac{V_1}{T_1} = \frac{V_2}{T_2} \) = Charles Law
  - \( \frac{P_1}{T_1} = \frac{P_2}{T_2} \) = Gay-Lussac’s Law
- 1661 Robert Boyle noted gas bubbles forming in the eye of a viper he exposed to a vacuum
  - Credited as the first description of DCS

HISTORICAL PERSPECTIVE

- Any exposure to low barometric pressures can cause inert gases (mainly nitrogen), normally dissolved in body fluids and tissues, to come out of physical solution and form tiny bubbles.
- DCS can occur during exposure to altitude (altitude DCS) or during ascent from depth (mining or diving).
- Salvage Operations from as early as 9th century BC pay scale based on depth of dive.
- 1841, first documented cases of DCS (Caisson Disease) were reported by a mining engineer who observed the occurrence of pain and muscle cramps among coal miners exposed to air-pressurized mine shafts designed to keep water out.
- 1869 first description of case resulting from diving activities while wearing a pressurized hard hat reported.

ALTITUDE RELATED EXPOSURE

- 1939- First reported case of DCS in altitude chamber trainee
- 1940 -1959: 17,000 cases of aviator’s decompression sickness (18 deaths)
- 1959: Navy chamber First successfully treated DCS case
- 1964: Research at Brooks confirmed efficacy of Hyperbaric O2 treatment

- 1854 Pol and Watelle, two physicians attending workers in a pressurized coal mine in Doucy, France, wrote the first medical report on mal decaisson.
- Followed by contributions from occupational physicians attending the caisson works at the Eads Bridge in St. Louis and the Brooklyn Bridge in New York.
  - Reported mortality 25%/year
  - Slowly decompression dropped the rate to 1.6%
Synovial “Bends”

- Lower extremity or abdominal pain made caisson workers bend over = BENDS
- Gas bubbles in synovial fluid → direct mechanical irritant vs. protein denaturation.
- Accounts for 60 - 70% of altitude DCS, and 80 - 90% of dive DCS.
- Upper extremity pain is more common, except in saturation divers.
- Avoid analgesics: may mask Type II symptoms.

Environmental Requirements

Oxygen

As altitude increases, available oxygen decreases.

- As pressure decreases, the air tends to expand and get thinner.
- The human body has several responses to changes in atmospheric pressure.

Environmental Requirements

Pressure

- Tiny Bubbles: According to Henry’s Law, when the pressure of a gas over a liquid is decreased, the amount of gas dissolved in that liquid will also decrease.
- When the body is exposed to decreased barometric pressures (as in flying an unpressurized aircraft to altitude, or during a rapid decompression), the nitrogen dissolved in the body comes out of solution, similar to what happens when you open a carbonated drink.
ATMOSPHERIC PRESSURE ABSOLUTE (ATA)

Two Atmospheres is all it takes
- Rapid decompression of ≥ 2 atmospheres allows nitrogen (and, to a lesser extent, CO₂) to form bubbles in any tissue or body fluid
- Synovial fluid (the “bends”)
- CNS/Spinal Cord/Vestibular (the “staggers”)
- Arterial/Venous/Pulmonary (the “chokes”)
- Skin (the “niggles”)
- Bone (dysbaric osteonecrosis)

HIGHEST RISK FOR DCS
- People flying in unpressurised aircraft at high altitude, such as,
  - Stowaways in unpressurised parts of the aircraft,
  - Passengers after failure of the cabin pressure vessel,
  - Pilots in an unpressurized cockpit, can suffer from decompression sickness

SUDDEN DECOMPRESSION

Loss of Atmosphere
- Barotrauma
  - Expansion of gas temporarily trapped in a body cavity (e.g. ear or sinus)
  - Pressure differences causing pain or injury
- Decompression sickness
  - Ambient atmospheric pressure = partial pressure of inert gases (e.g. nitrogen)
  - Nitrogen forms bubbles in bloodstream
  - “Bends” (pains in joints and muscles)
  - “Chokes” (gas emboli)
  - Neurological symptoms (weakness, convulsions, syncope)

Trapped Air
- There are several places in the human body where air can get trapped. The ear, the sinuses, and the stomach and intestines are a few examples.
American Osteopathic College of Occupational and Preventive Medicine
2014 Annual Meeting, Seattle, Washington

Trapped Air
As you go up in altitude, air expands... if this air is trapped, expanding air can lead to pain. A blocked Eustachian tube could lead to pain in the middle ear.

• Usually expanding air is not a problem since it can be released.
• When you come back down after being at altitude, the expanded air gets smaller... if this occurs in a closed space it creates a vacuum effect...This is a BIG problem.

Ear Block
• If you fly with a cold these passages can swell up enough to block the passage of air, especially when you are trying to get air in to equalize pressure on descent.
• Leads to a painful ear or sinus block!

Do Not Fly with a Cold!

Sinus Blocks and Ear Blocks
• There are spaces in the sinuses and middle ear where air can get trapped.
• Under normal conditions this air can escape through passages to the outside (Eustachian tube)

Other effects of pressure
• DECOMPRESSION SICKNESS
  – Air bubbles can form in the body if you go to high enough altitudes
  – These bubbles are made of nitrogen and usually dissolve as you descend.

Decompression Sickness
– Bubbles that do not dissolve can get trapped in the joints and cause pain (bends)
– If they form in the blood and go to the brain they can cause serious neurologic symptoms.
PATHOPHYSIOLOGY

- If N2 is forced to leave solution too rapidly:
  - Tiny bubbles form in different areas of the body, causing a variety of signs & symptoms.
  - Although bubbles can form anywhere in the body, the most frequently targeted anatomic locations are the shoulders, elbows, knees, and ankles.
  - Most Common are “The bends” (joint pain) account for about 60 to 70% of all altitude DCS cases. With the shoulder being the most common site.
  - Neurologic manifestations are present in about 10 to 15% of all DCS cases, headache & visual disturbances being the most frequent symptoms.
  - “The chokes” are very infrequent & occur in less than 2% of all DCS cases.
  - Skin manifestations are present in about 10 to 15% of all DCS cases.

DCS RISK FACTORS

- Heart muscle birth defects, including patent foramen ovale, atrial septal defect and ventricular septal defect (AGE)
- Being older than 30
- Being female
- Low cardiovascular fitness
- High percentage of body fat (nitrogen is lipid soluble)
- Use of alcohol or tobacco
- Fatigue, seasickness or lack of sleep, dehydration
- Musculoskeletal Injuries (old or current) (scar tissue decreases diffusion)
- Cold Environment
- Lung disease (bullae rupture AGE)
- Exposure to closed, pressurized spaces during construction of tunnels
- Compressed-air divers
- Altitude and dive chamber exposure
- Aircraft cabin decompression
- High-altitude parachute operations
- Other exposures to ≥ 2 atm. Decompression

ALTITUDE DCS Causes

- Predisposing causes:
  - Flying or going to higher altitude soon (12-24 h) after diving (This increases the pressure gradient.)
  - Smoking
  - A principal cause of DCS is rapid DECOMPRESSION at altitude.
  - Predisposing environmental factors
    - Cold vasoconstriction decreases nitrogen offloading
    - Heavy work (vacuum effect in which tendon use causes gas pockets)
    - Rough flight conditions
    - Heat exposure (leads to dehydration)

Stresses of Flight

- Pre-flight
  - Reservations and travel to airport, parking
  - Baggage handling, standing in long lines
  - Walking long distances, security screening/searches
  - Emotional stress
  - Electronic interface (man-machine) challenges
  - Crowds, congestion and noise
- In-flight Hazards
  - Subsonic flight to 40K ft avoid turbulence minimize drag and increases fuel economy
  - Hostile environment external to skin of AC

Stresses of Flight

- In-flight Hazards
  - Enclosed in a cabin built to protect PAX from hostile external environmental risks and physiological threats, a stressor even for the healthiest of us
  - In a micro-environment for hours that attempts to balance health and comfort
  - External temp below – 50degrees C
  - Ambient air pressure: 140 mm Hg or 1/5 pressure at sea level, PaO2 will not sustain life, thus pressurized cabins for flights above 10K ft.
  - Lower barometric pressure—Max permitted cabin altitude @8000ft: 565mmHg; PaO2=55mmHg; O2sat=90%
    - OK for healthy person without ASVD/RESP deficiencies/non-alcoholic induces high level cognitive performance impact
    - Ozone removed via catalytic filters
Stresses of Flight

- **In-flight Hazards (continued):**
  - Low humidity (10-20%) (corneal hypoxia w/contacts, mucous membranes, skin) local symptoms not systemic dehydration
  - Noise & vibration (including turbulence)
  - Cosmic ionizing radiation & pregnancy (occupational hazard for frequent long haul flying): atmosphere, aluminum skin and cellular repair of any damage minimizes PAX risk. Greater risk for cellular damage and CA in the Young & female + More high flying. PG wastage 1° 24 hours!
  - Lack of mobility - Cramped seating (“the economy class syndrome” & DVT, droplet microorganism spread)
  - Jet lag (E >> W)
  - Smoking on overseas carriers, quality of HEPA filtered cabin air with 50% recirculated 10 – 15 x per hour, intake air is sterile and dry, proximity for IF Ds transmission and dilution

**ATMOSPHERIC EXPOSURE COUNTERMEASURES**

**HISTORY**

Ask the patient about the following symptoms:

- General symptoms of profound fatigue or heaviness, weakness, sweating, malaise, or anorexia
- Musculoskeletal symptoms of joint pain, tendinitis, crepitus, back pain, or heaviness of extremities
- Mental-status symptoms of confusion, unconsciousness, changes in personality
- Eye and ear symptoms of scotomata (negative then positive), diplopia, tunnel vision, blurring, extraocular motor paresis, tinnitus, or partial hearing loss
- Skin symptoms of pruritus or motting
- Pulmonary symptoms of dyspnea, nonproductive cough, or hemoptysis
- Cardiac symptoms of inspiratory, substernal, or sharp or burning chest pain
- Gastrointestinal symptoms of girdle abdominal pain, fecal incontinence, nausea, or vomiting
- Genitourinary symptoms of urinary incontinence or urinary retention
- Neurologic symptoms of paresthesia (general or over a joint), paresis, paralysis, migrainous headache, vertigo, dysarthria, or ataxia
- Lymphatic symptoms of edema

**ALTITUDE DCS SPECIFIC HISTORY**

- **MAJOR VARIABLES FOR ALTITUDE DCS**
  - Altitude
  - Exposure time at altitude
  - Exercise at altitude
  - Pre-oxygenation (pre-breathing)
  - Subject Variability-hardest to account for
DCS SYMPTOMS

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Percentage of All Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localized pain</td>
<td>91.8%</td>
</tr>
<tr>
<td>Neurologic paresthesia</td>
<td>21.2%</td>
</tr>
<tr>
<td>Muscular weakness</td>
<td>20.8%</td>
</tr>
<tr>
<td>Discoloration</td>
<td>6.1%</td>
</tr>
<tr>
<td>Headache</td>
<td>0.8%</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>7.6%</td>
</tr>
<tr>
<td>Fatigue</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

Adapted from Ruan JC. Decompression sickness amongst divers: an analysis of 135 cases. Mil Med. 1965;130(3):14-34

PHYSICAL FINDINGS
- May include any of the following signs:
  - **General** - Fatigue, shock
  - **Mental status** - Disorientation, mental dullness
  - **Eyes** - Visual field deficit, papillary changes, air bubbles in the retinal vessels, or nystagmus
  - **Mouth** - Liebermeister sign (a sharply defined area of pallor in the tongue)
  - **Pulmonary** - Tachypnea, respiratory failure, respiratory distress, or hemoptysis
  - **Cardiac** - Tachycardia, hypotension, dysrhythmia, or Hamman sign (crackling sound heard over the heart during systole)
  - **Gastrointestinal** - Vomiting
  - **Genitourinary** - Urinary bladder distention, decreased urinary output
  - **Neurologic** - Hypoesthesia, hypoesthesia, paraparesis, anal sphincter weakness, loss of bulbocavernous reflex, spotty motor or sensory deficits, seizures, or ataxia
  - **Musculoskeletal** - Subjective joint pain without objective findings, or decreased range of motion because of muscle splinting of involved joint or tendon
  - **Lymphatic** - Lymphedema
  - **Skin** - Pruritus, mottling/marbling, hyperemia, violaceous color, cyanosis, or pallor

PULMONARY AIR GAS EMBOLI

Diagnostic maneuvers
- Pain, frequently musculoskeletal, occurs in 50-60% of DCS cases.
- Two specific maneuvers can aid the practitioner in diagnosing DCS.
  - Place a large BP cuff over the area of pain & inflate it to 150-250 mm Hg. If patients has nitrogen bubbling in the joint or tendons, this increase can force some of the nitrogen back into solution, resulting in a temporary decrease in pain.
  - Milking the muscle toward the affected joint may increase pain by pushing more nitrogen bubbles toward the joint

Differentiating between AGE and DCS
- **AGE** - (1) Any DCS can cause AGE, (2) the onset is immediate (< 10-120 min), and (3) neurologic deficits manifest in only the brain.
- **DCS** - (1) The DCS must be of sufficient duration to saturate tissues, (2) the onset is latent (6-36 h), and (3) neurologic deficits manifest in spinal cord and brain.

Differential Diagnoses
- Alcohol/Substance Abuse Eval
- Anaphylaxis
- Atrial Fibrillation/AMI
- Back Pain, Mechanical
- Barotrauma
- Bronchitis
- Bursitis
- Cervical Strain
- CHF/Pulmonary Edema
- DVThrombosis/Thrombophlebitis
- Dermatitis, Contact
- Dysbarism/Eosinophilitis
- Epidural Hematoma
- Glaucoma, Acute Angle-Closure
- Headache, Migraine
- Heat Exhaustion/Heatstroke
- Hyperventilation Syndrome
- Hypoglycemia
- Hypothermia
- Labyrinthitis
- Lionfish/Stonefish
- Octopus Envenomations
- Pneumothorax/Iatrogenic, Spontaneous/Pneumomediastinum
- PE
- Retinal A/V Occlusion
- Retinal Detachment
- Shock, Hypovolemic
### Categorization of DCS

- **Type I**: usually mild and self-limited
  - Limb pain
  - Gradual onset, poorly localized at first.
  - Localizes to a throbbing ache.
  - Inflating BP cuff over affected area often relieves the pain, which distinguishes it from ischemia, infection, and nerve entrapment.
  - **RED FLAGS**: Sharp, shooting, encircling or migratory pain/tingling; burning trunk pain (these are CNS symptoms. Not Type I.)

- **Type II**: requires aggressive treatment
  - Neurological symptoms
  - Cardiorespiratory symptoms
  - Inner ear symptoms
  - Cardiovascular decompensation

50% of ADS cases become symptomatic within 30 min.; 85% by one hour; only 1% after 6 hours. Symptoms may persist days to weeks.

Type I may co-occur with Type II. Don’t dismiss symptoms as “only Type I” until you’ve looked for and excluded the more serious symptoms.

- **Type I**: Skin/lymphatic, mild localized MSK pain
- **Type II**: Trunk pain/paresthesia's; Cardiac; Respiratory; CNS/spinal cord
Categorization of DCS

<table>
<thead>
<tr>
<th><strong>Type II: requires aggressive treatment</strong></th>
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</thead>
<tbody>
<tr>
<td><strong>Neurological symptoms</strong></td>
</tr>
<tr>
<td>- Unexplained fatigue is a common harbinger of DCS</td>
</tr>
<tr>
<td>- Any neurological symptoms following a decompression exposure should be considered Type II DCS until proven otherwise.</td>
</tr>
<tr>
<td>- Bilateral pain in the trunk and hips should be considered Type II DCS.</td>
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Categorization of DCS

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<td><strong>Cardiorespiratory symptoms</strong></td>
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<tr>
<td>- Intravascular bubbling may occlude pulmonary circulation, causing “the chokes:”</td>
</tr>
<tr>
<td>- burning substernal chest pain, worse w/breathing</td>
</tr>
<tr>
<td>- cough</td>
</tr>
<tr>
<td>- dyspnea</td>
</tr>
<tr>
<td>- may progress to circulatory collapse, LOC, and death</td>
</tr>
<tr>
<td>- Recompression ASAP</td>
</tr>
<tr>
<td>- Approx. 5% to 10% of Type II Altitude DCS</td>
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<td><strong>Cardiorespiratory symptoms</strong></td>
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<tr>
<td>- Arterial gas bubbles may affect any vascular bed</td>
</tr>
<tr>
<td>- CNS</td>
</tr>
<tr>
<td>- Middle ear</td>
</tr>
<tr>
<td>- Heart</td>
</tr>
<tr>
<td>- Needs immediate recompression</td>
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<tr>
<td>- Vertigo</td>
</tr>
<tr>
<td>- Tinnitus</td>
</tr>
<tr>
<td>- Hearing loss</td>
</tr>
<tr>
<td>- Difficult to distinguish from round or oval window rupture. ? Perilymph fistula.</td>
</tr>
<tr>
<td>- Most common in long-duration helium-oxygen dives.</td>
</tr>
</tbody>
</table>
Categorization of DCS

- **Type II**: requires aggressive treatment
  - Cardiovascular decompensation
    - Most common with diving. Usually occurs on ascent, or within 10 minutes of surfacing.
      - Chest pain, cough and dyspnea may progress rapidly to shock and cardiovascular collapse.
      - Need to distinguish between gas emboli, Pulmonary Overinflation Syndrome (i.e., breath-holding on ascent) and pneumothorax/mediastinum
    - Blood-tinged frothy sputum suggests overinflation/alveolar rupture.
    - **DECOMPRESSION** is initial treatment for all of these.

Arterial Gas Embolism (AGE)

- Can be the result of DCS alone; but remember to look for alveolar rupture w/air embolism in divers.
- Patent foramen ovale may allow venous gas bubbles to migrate into arterial circulation.

Dysbaric Osteonecrosis

- Result of repetitive (nitrogen) embolization after decompression. Because fat cells tend to absorb large quantities of dissolved nitrogen, rapid expansion of these cells in the marrow can cause increased intraosseous marrow pressure and vascular compromise.
  - Infarcts at joint surfaces may cause DJD.
  - Caisson workers repeatedly exposed to > 3 atm. Pressure for > 3 hrs. are at particularly high risk.
  - Strong association with repetitive “deep dives.” (> 200m)
  - Conservative recompression schedules probably reduce the risk.

DEFINITIVE THERAPY

Transport via ground or low altitude aircraft, to nearest ED WITH hyperbaric facility, if feasible, and try to keep all gear with the aviator/diver.

- Treat the patient for nausea, vomiting, pain, and headache
- **HBO treatment**
  - Patients with Type I or mild Type II DCS can dramatically improve and have complete symptom resolution.
  - This improvement should not dissuade practitioner from HBO referral or transfer, as relapses have occurred with worse outcomes.

Laboratory Studies

- No specific tests exist for decompression sickness (DCS). Obtain baseline laboratory studies, but these will have no bearing on initial management. They may be useful in the differential diagnosis while HBO therapy is administered.
- **Do not delay HBO therapy (and transfer, if necessary)**. In individuals with change in mental status, prudence dictates obtaining studies to help further evaluation. If the individual is in extremis (e.g., shock), obtain appropriate resuscitation studies.

Laboratory Studies

- **Change in mental status**
  - Blood glucose level, CBC
  - Sodium, magnesium, calcium, and phosphorous levels
  - Oxygen saturation
  - Ethanol level and drug screen
  - Carboxyhemoglobin level
- **Shock**
  - Blood glucose level, CBC
  - Electrolytes and BUN level
  - Creatinine levels
  - Type and screen/cross
  - Prothrombin time, activated partial thromboplastin time
  - Carboxyhemoglobin level
Imaging Studies

Chest radiography:
- Because dysbaric injuries involving lungs/chest can occur concomitantly with DCS, obtain a chest radiograph to screen for over pressurization injuries WITH evidence of pneumothorax, pneumomediastinum, subcutaneous emphysema, pneumopericardium, alveolar hemorrhage, and decreased pulmonary blood flow caused by nitrogen pulmonary emboli.

Head CT scan: If mental status does not initially improve in response to hyperbaric repressurization, consider other etiologies.

MRI has been found useful in the management of neurologic DCS. The diagnosis is still clinical, the patient's transfer to an HBO facility should not be delayed.
- has revealed focal spinal lesions that correlated with patient's symptoms & examination, readily detects cerebral damage in AGE but yields low sensitivity in DCS.
- may prove useful in patients who do not show initial improvement to HBO therapy & may localize the area of DCS injury or exclude other etiologies for the patient's symptoms.
- Spinal MRI found lesions more commonly in divers with severe spinal DCS, none at all in those that ultimately had a favorable outcome. In an HBO center, it may be a useful diagnostic adjunct to help guide management.

Imaging Studies

MRI is also useful for monitoring injured divers through successive HBO treatments.
- Cerebral MRI has identified abnormalities in the brain that correlated with hours of diving in AIR Breathing range even when no clinical or historical signs of neurologic DCS were present.
- Negative MRI findings cannot be used to exclude AGE or DCS. Improvement in MRI findings does not necessarily correlate with clinical improvement. It has also been correlated with neuropsychological deficits in older divers.
- The decision to pursue HBO referral is based on clinical presentation and should not be guided by MRI findings.

Treatment of DCS

- RECOMPRESSION per Navy Dive Tables.
- Supplemental O₂, IV fluids, analgesics.
- Supportive care until recompression.
- Cutaneous bends do not always require recompression - but observe closely.
- Limit further exposure.
- Avoid strenuous exertion.

HBO treatment
- Mild type I DCS probably do not require treatment other than breathing pure oxygen at sea level for a short time. Type I DCS symptoms do require close observation, as symptoms may portend onset of more serious problems requiring hyperbaric recompression. The only effective treatment for gas embolism is recompression; other treatments are merely for symptoms.
- Several types of hyperbaric chambers exist, ranging from small monoplace (single person) chambers to complex multiple place, multiple lockout chambers large enough for multiple patients and attendants. All have ability to maintain critical care monitoring & mechanical ventilation. Some patients experience claustrophobia with the small monoplace chambers. Increased oxygen toxicity issues have been reported with the monoplace chambers because the entire environment is oxygenated, whereas, with the larger chambers, patients breath the oxygen via mask, but the ambient environment is not supplemented with O₂.

Administer 100% oxygen, intubate if necessary, and intravenously administer saline or lactated Ringer solution.
- Administer 100% oxygen to wash nitrogen out of lungs & set up an increased diffusion gradient to increase nitrogen offloading from the body.
- Aspirin is commonly considered and given in diving accidents for antiplatelet activity if the patient is not bleeding. There are no current data to support this practice NOR showing a benefit for other adjunctive treatments, recompression with helium/oxygen/NSAIDS.
- Perform CPR/ACLS, if required, as well as needle decompression of the chest if tension pneumothorax is suspected.
- Do Not put the patient into the Trendelenburg position. process actually increases intracranial pressure & exacerbates injury to the blood-brain barrier. It also wastes time & complicates movement PT.
Basic HBO theory

- To repressurize the patient to simulate a depth where the bubbles from nitrogen or air are redissolved into the body tissues and fluids.
- By breathing intermittently higher concentrations of oxygen, a larger diffusion gradient is established, with patient taken slowly back to surface atmospheric pressure, allowing gases to diffuse gradually out of the lungs & body.
- Addition of helium to oxygen has been shown to yield an advantage over oxygen alone even in severe neurologic DCS or treatment-refractory DCS
- Consult a diving medicine or HBO specialist for all diving-related injuries. Visit their DAN Web site at Divers Alert Network
  - DAN America: 1-919-684-8111 or 1-919-684-4DAN (4326) (accepts collect calls)

Pre-flight Medical Assessment

- Must address all medical problems in light of all the potential hazards & their negative impact on each medical condition and therapeutic intervention to produce a medical risk assessment for each PAX.
- IOT optimize treatment well before departure and educate on recognition of potential in-flight problems
- Hypobaric and hypoxic hazards effects on age and sex
- Range of gas expansion on all organ systems especially recent surgical and interventional procedures.
- Ambulation (ambulance, WC, charts, boarding and deplaning assistance, altitude impact on endurance, mobility and leg space
- Carry and take all meds Rx at destination HR docs, refrigerated meds, MEDIF doc to inform air carrier of requirements and need of aviation specific O2 (IDDM and OCP)

MEDEVAC In-flight Medical Care

- Aircrew training CPR AED VS, First aid kit
  - Bandages; splints; tape & scissors; inhalants; gloves
- AED (US carriers by 12 Apr 2004)
- Medications (US carriers by 12 Apr 2004)
  - 50% dextrose; 1:1,000 & 1:10,000 epinephrine; IV & PO
  - Phenylephrine; oral analgesic; ASA; NTG; inhaler; IV admin sets; syringes; needles; IV NS; IV atropine; lidocaine
- Oxygen: pre-approved & certified cylinders & O2 concentrators
  - Not pre- or post-flight; must have arrangements with vendors
  - NOT using drop-down masks!
- Equipment (US carriers by 12 Apr 2004) varies by airline
  - Sphygmomanometer: BP cuff; three sizes of oral airways/masks; BVM
- Telemedicine capability becoming a reality
- Good Samaritan laws/declaration of death & territory jurisdiction

CAUTION: O2 THERAPY

- Side Effects may include some or all of the following:
  - Sound sleep and alert wakefulness, increased metabolism healthy appetite, energy to spare and tolerance toward others.
  - There may be an increased comprehension level, sincerity and an ability to think more clearly.
  - Increased self-esteem may lead to positive attitudes and assimilation of new ideas and ideals.
  - an increased level of willingness to work and play well with others.
  - Increased attention span and the ability to remain calm in the midst of chaos
  - additional creativity, open-mindedness, charity, daily exuberance, enthusiasm, passion and prolonged sexual performance.
- Due to the nature of increased oxygen, those with symptoms of bad body parts should consult with their physician for advice regarding participation of increased oxygen consumption.