EMERGENCY DIVE PLAN 2021

Dive Accidents

- Estimated 3 million certified recreational divers in the United States
- Millions of dives annually
- Approximately 700-1200 US and Canadian residents treated in dive accidents annually
- Approximately 80 fatalities annually US & Canadian citizens

DCI on the Emerald Coast 2018/2019

- Springhill Medical Center – 11 cases of DCI treated
  - 2019 – 10 cases
- NAS NAMI – 8 cases of DCI treated (active military, military dependent or retirees)
  - 2019 – 2 cases
- Gulfport Memorial – 2 cases of DCI treated
  - 2019 – 0 cases

DCI on the Emerald Coast 2020

- Advent Health Orlando, Orlando, FL
  - 11 DCI patients
- West Jefferson Hospital, New Orleans, LA
  - 11 DCI patients
- Springhill Medical Center, Mobile, AL
  - 11 DCI patients
- Gulfport Memorial Hospital, Gulfport, MS
  - 3 DCI patients
- Pensacola NAS, Naval Station Pensacola, FL
  - 1 DCI patient
- St. Mary's Hospital, West Palm Beach, FL
  - ~35 DCI patients
- Mercy Medical Center, Miami, FL
  - 83 DCI patients

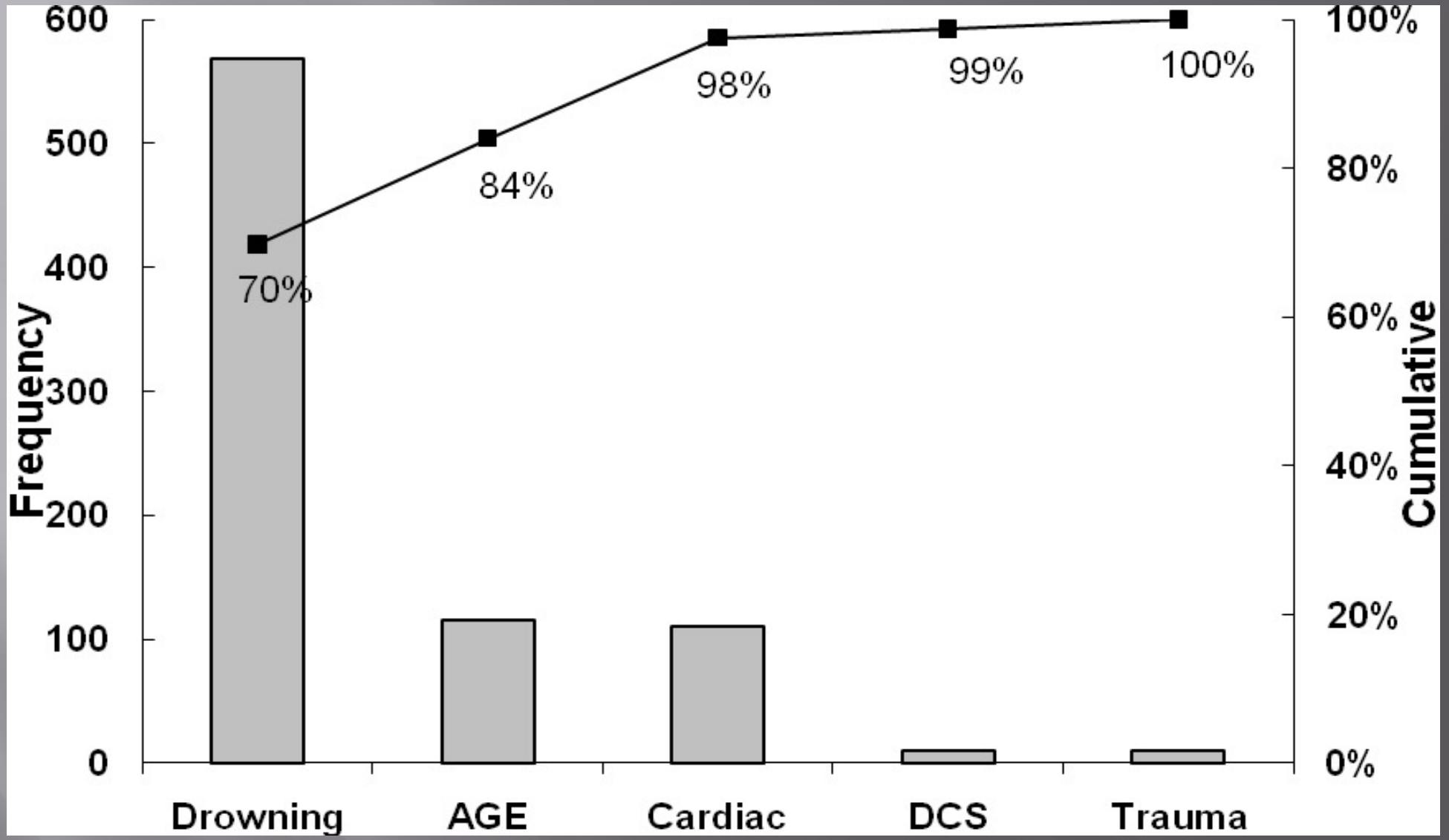
DCI on the Emerald Coast 2021

- To date 7 DCI patient treated
  - 4 females/3 males
  - 26 – 67 years of age
  - 5 type II, 2 type I

Pulmonary Barotrauma and Arterial Gas Embolism

BOYLE'S LAW

- **Pressure and Volume are inversely proportional**
  - **Increase the pressure decrease the volume**
  - **Decrease the pressure increase the volume**
- **The Greatest Relative Pressure Change**
  - First 10 fsw
- **The Most Common Depth Range For Ear & Sinus Blocks**
  - First 10 fsw
- **PBT in as little as 4 fsw**



Cause of death in 814 DAN America scuba fatalities

Denoble et al. Scuba Injury death rate among insured DAN members. Diving and Hyperbaric Medicine. 2008; 38: 182-188.

4 General Reasons for Fatalities

- Poor Diver Health
  - Obesity, High Blood Pressure, Coronary Artery Disease, General lack of fitness
- Procedural Errors
  - Buoyancy control, rapid ascents, missed deco's, failing to monitor air supply
- Environmental Issues
  - Cold water, sudden storms
- Equipment Problems
  - Improperly maintained equipment

Terminology

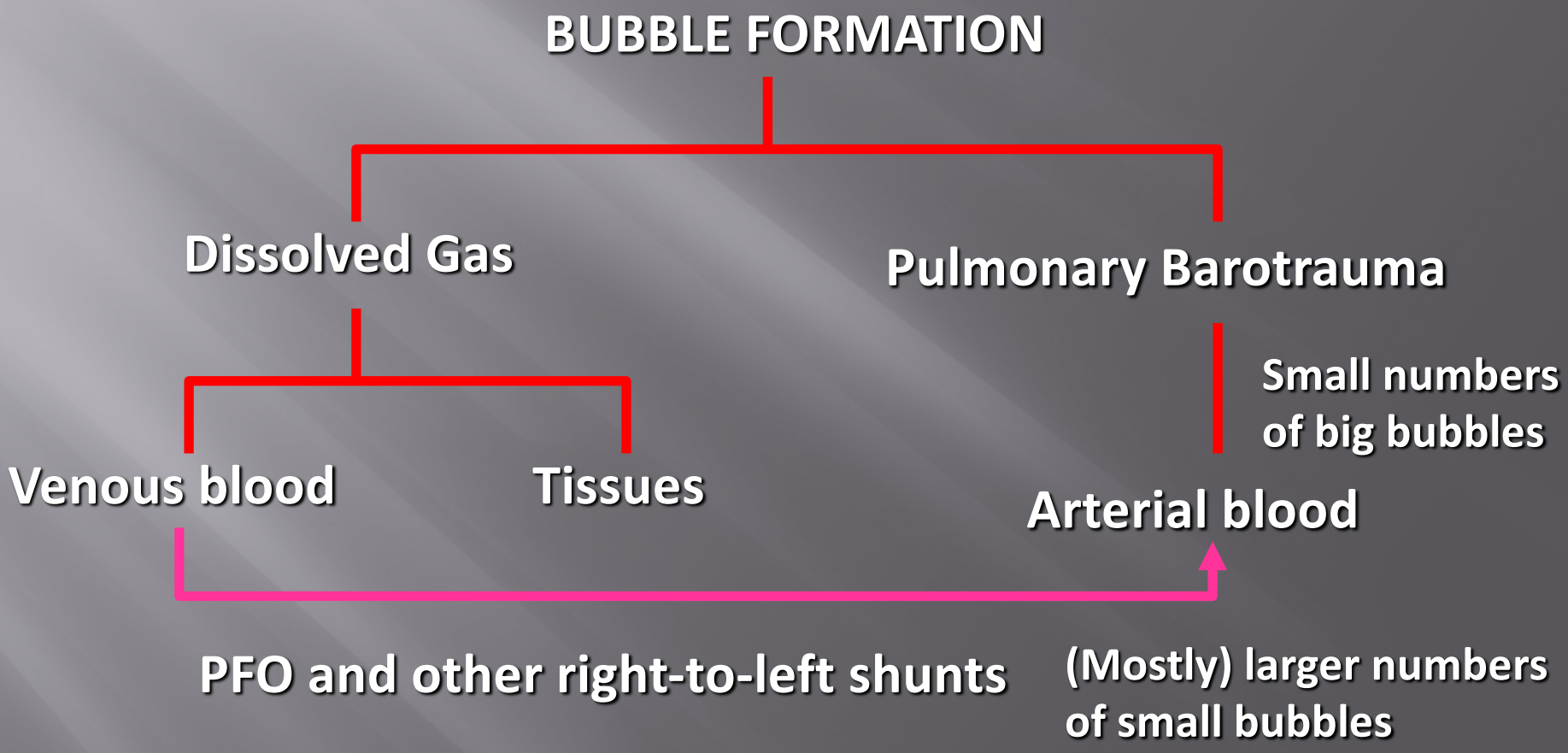
- **DCS – disease state secondary to expansion of dissolved inert gas**
- **AGE – gas bubbles in the arterial system either from pulmonary barotrauma or cardiac defect**
- **DCI – either of the above or both**

Bubble Sources

- **Arterial Gas Embolism (AGE) – arises from escape of air from the pulmonary vasculature into the arterial circulation**

- **Arterial gas emboli may also arise from the venous system through a right-to-left shunt**
  - **PFO**
  - **Vascular abnormality**

Sources of Arterial Bubbles in DCI



Courtesy of Dr. Simon Mitchell

Pulmonary Barotrauma

- Expanding gas may damage respiratory tissue during ascent
- Contributing Factors (theories)
  - air trapping
  - adjacent areas of differing compliance

AGE is primary concern

Pulmonary Barotrauma

- **Consequences**
  - **introduction of air into pulmonary veins**
  - ***pneumothorax***
  - ***mediastinal emphysema***
- **Air in pulmonary veins commonly distributes to the cerebral circulation**
- **Cerebral arterial gas embolism (CAGE)**
  - **Bubbles may be large and cause dramatic rapid onset of symptoms**

Arterial Gas Embolism

AGE

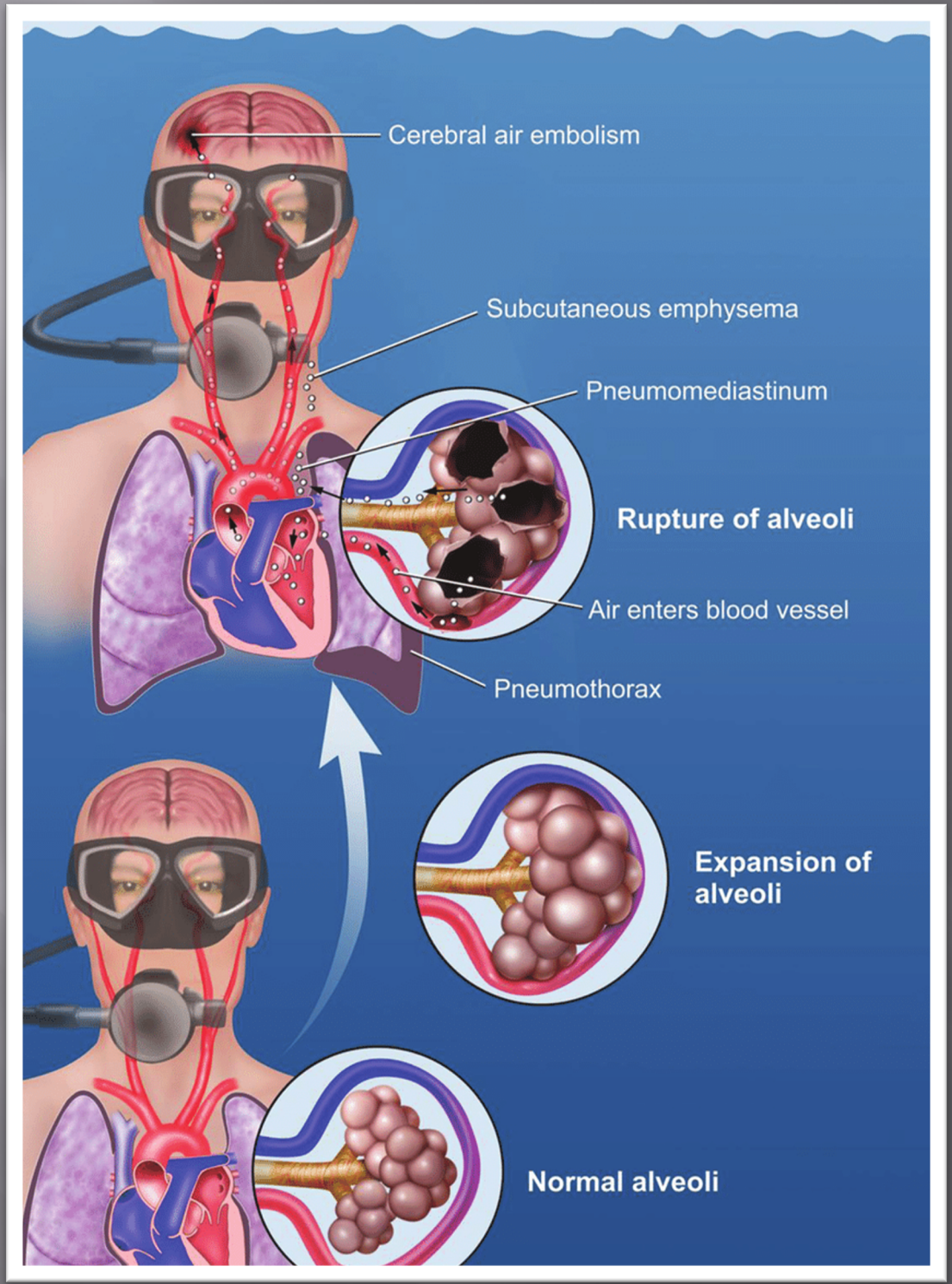
Neural signs and symptoms that result from air emboli that have entered the arterial system, travelled to the brain and interrupted blood flow to the point where normal function is impaired

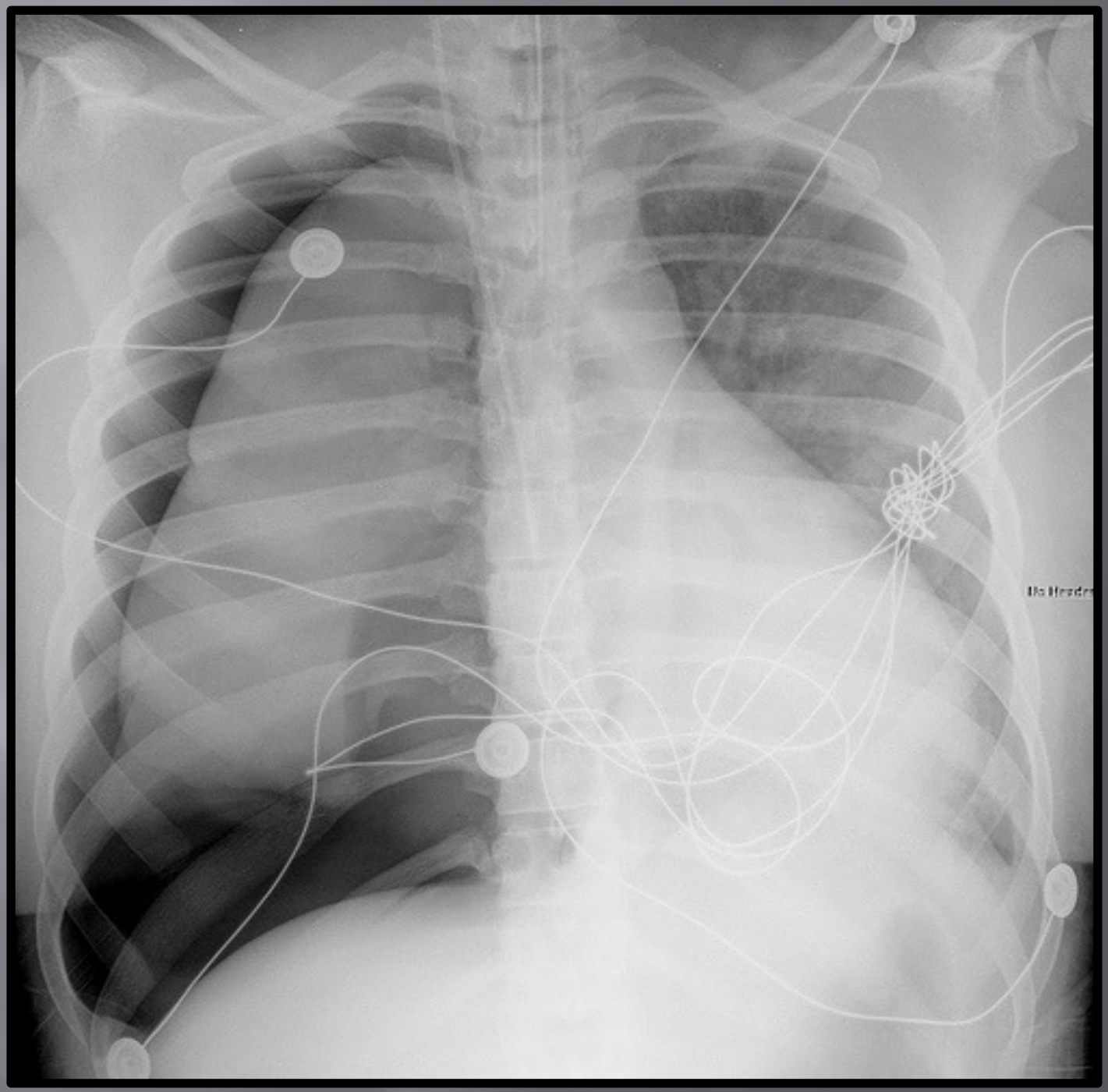
- Confusion
- Ataxia
- Cognitive disruption
- Loss of coordination
- Loss of consciousness
- Death

Presentation of AGE

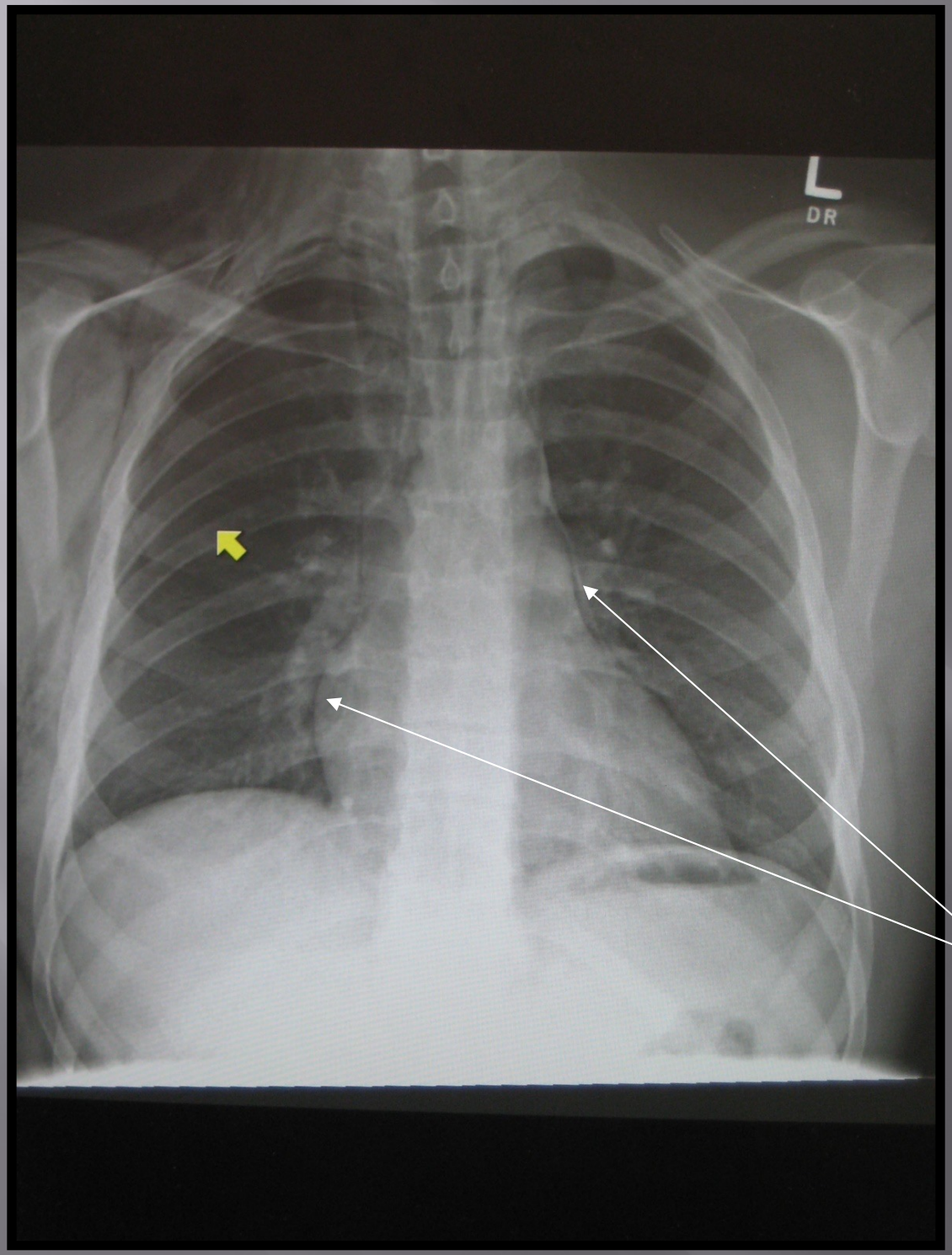
- **AGE, by definition is associated with PBT**
- **Radiographic evidence in less than half of AGE victims**

Bove and Davis. 2004


Cerebral air embolism
Subcutaneous emphysema
Pneumomediastinum
Rupture of alveoli
Air enters blood vessel
Pneumothorax
Expansion of alveoli
Normal alveoli



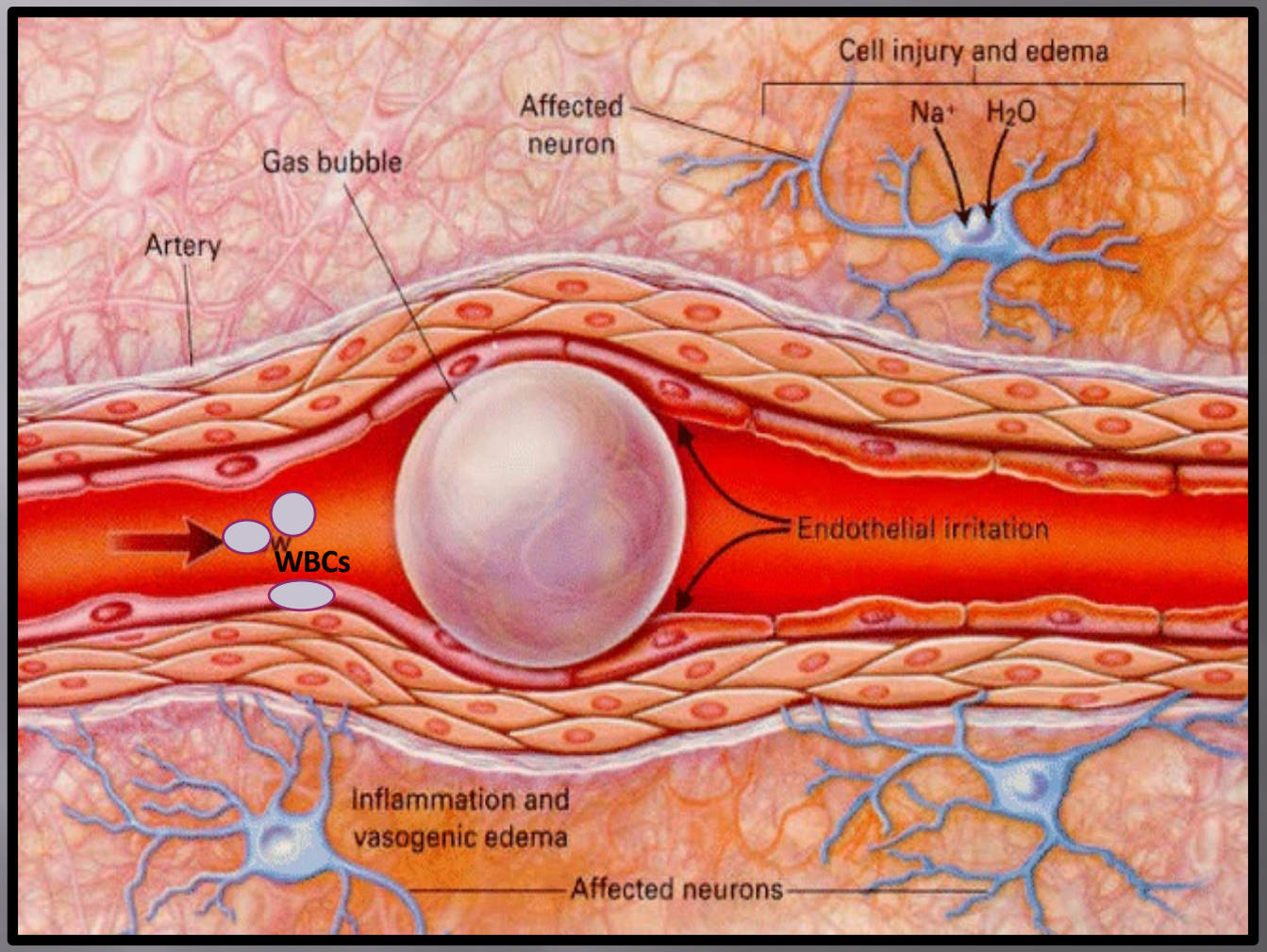
Right Pneumothorax



Pneumomediastinum

Free Air
Around the Heart

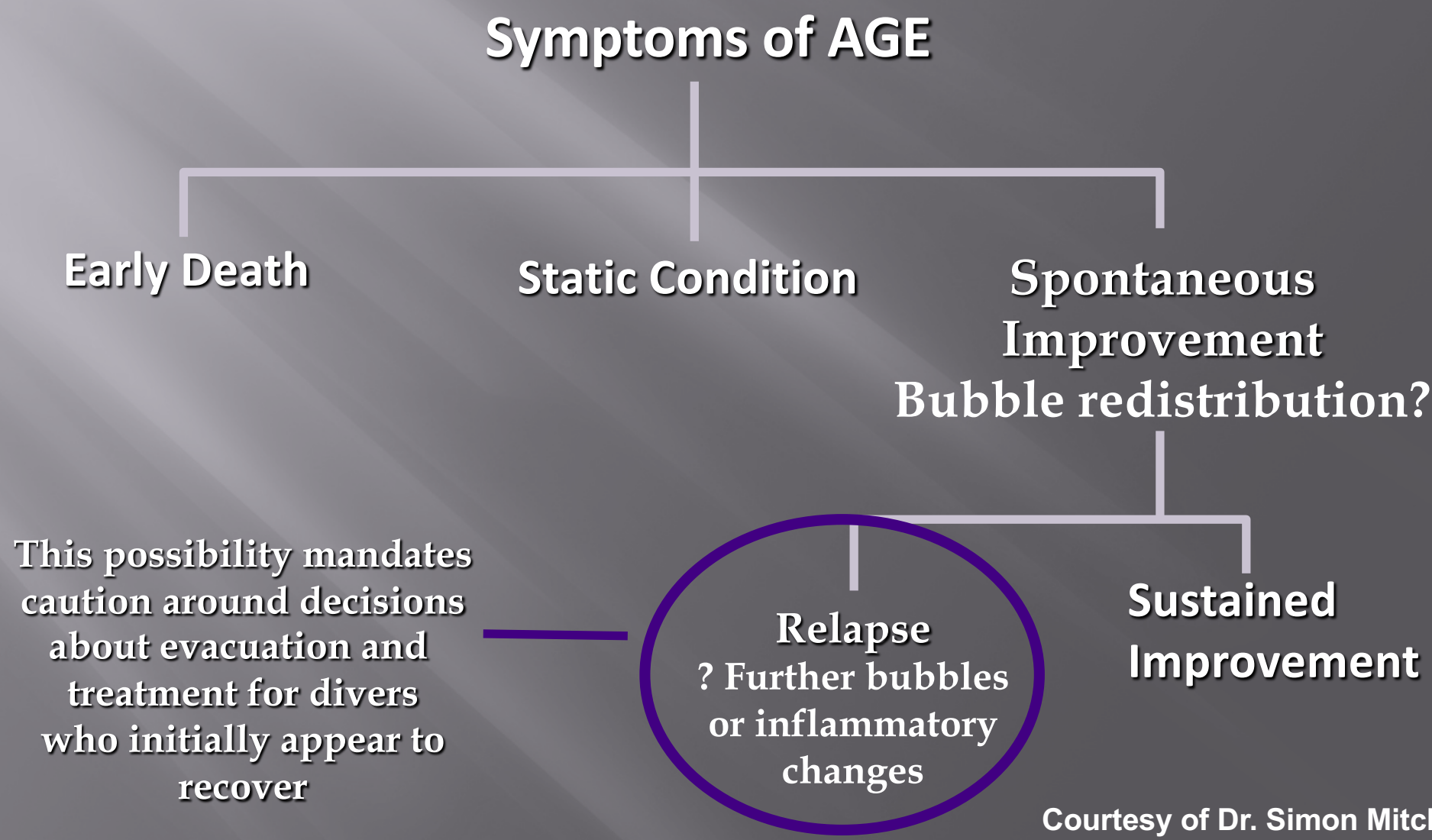
Arterial Gas Embolism



Bubbles damage endothelium with their passage →white cell adhesion and systemic inflammation

Muth CM, Shank ES. New Eng J Med 2000;347:476-82

Natural History of AGE



Courtesy of Dr. Simon Mitchell

AGE vs. DCS

- AGE
  - 85% in 5 min
  - 100% in 10 min
  - Serious neurologic sx
- DCS
  - 50% < 1 hr
  - 90% < 6 hrs
  - 99% < 24 hrs

"Great Mimicker"

Treatment Considerations

- PBT ≠ CAGE
- CAGE ≠ detectable PBT
- PBT alone does NOT require Recompression
- Neural symptoms attributed to bubbles do "require" recompression

Treatment Considerations

- **Pulmonary Barotrauma requires stabilization prior to recompression**
- **CXR before recompression!**

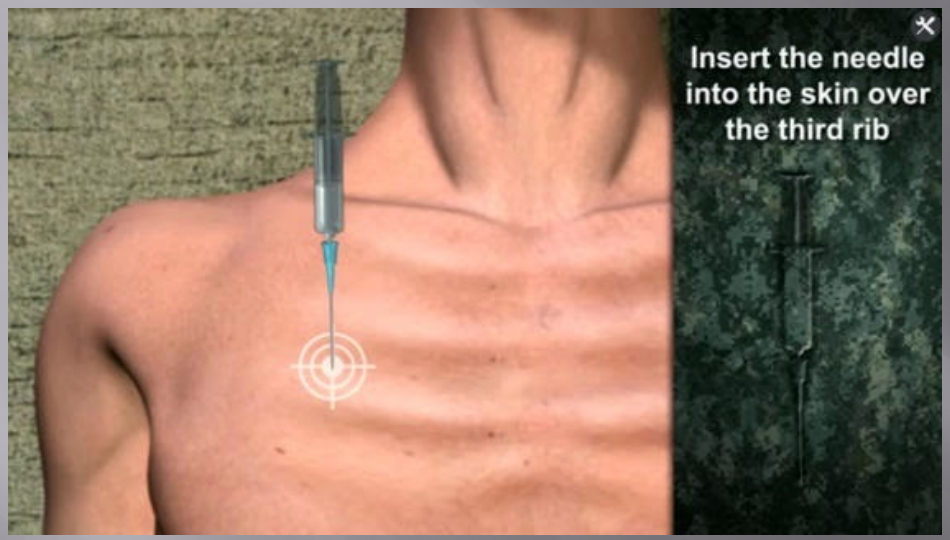
Treatment

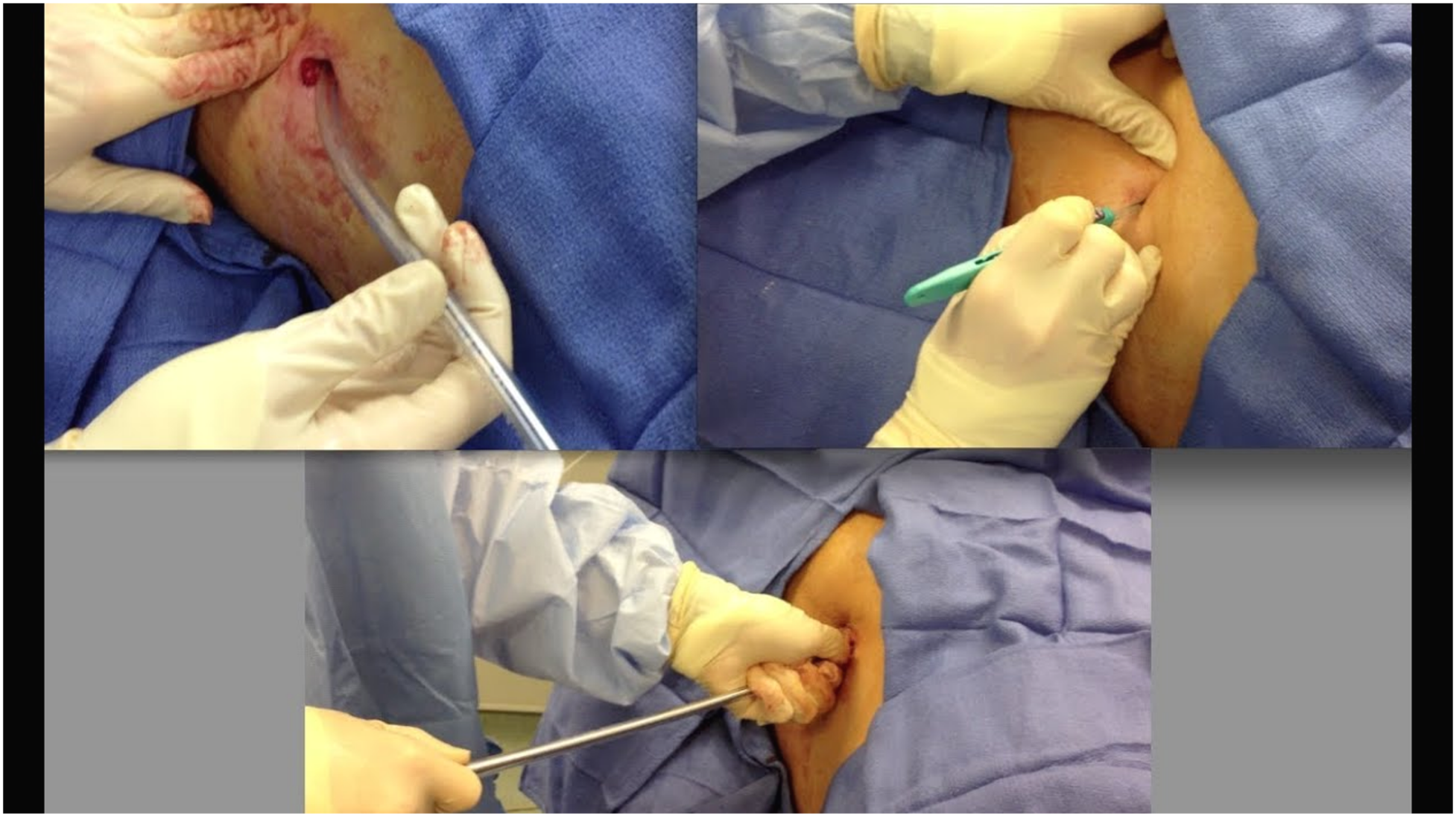
SLO_2 is the standard pre-hospital care in all cases of diving related injury, especially with neurological symptoms

Treatment

- Mediastinal emphysema – tx with SLO_2
- Pneumothorax – tx with pulmonary decompression with a needle or chest tube
- CAGE – ensure pulmonary stabilization, then tx with TT6

Needle Decompression of a Pneumothorax



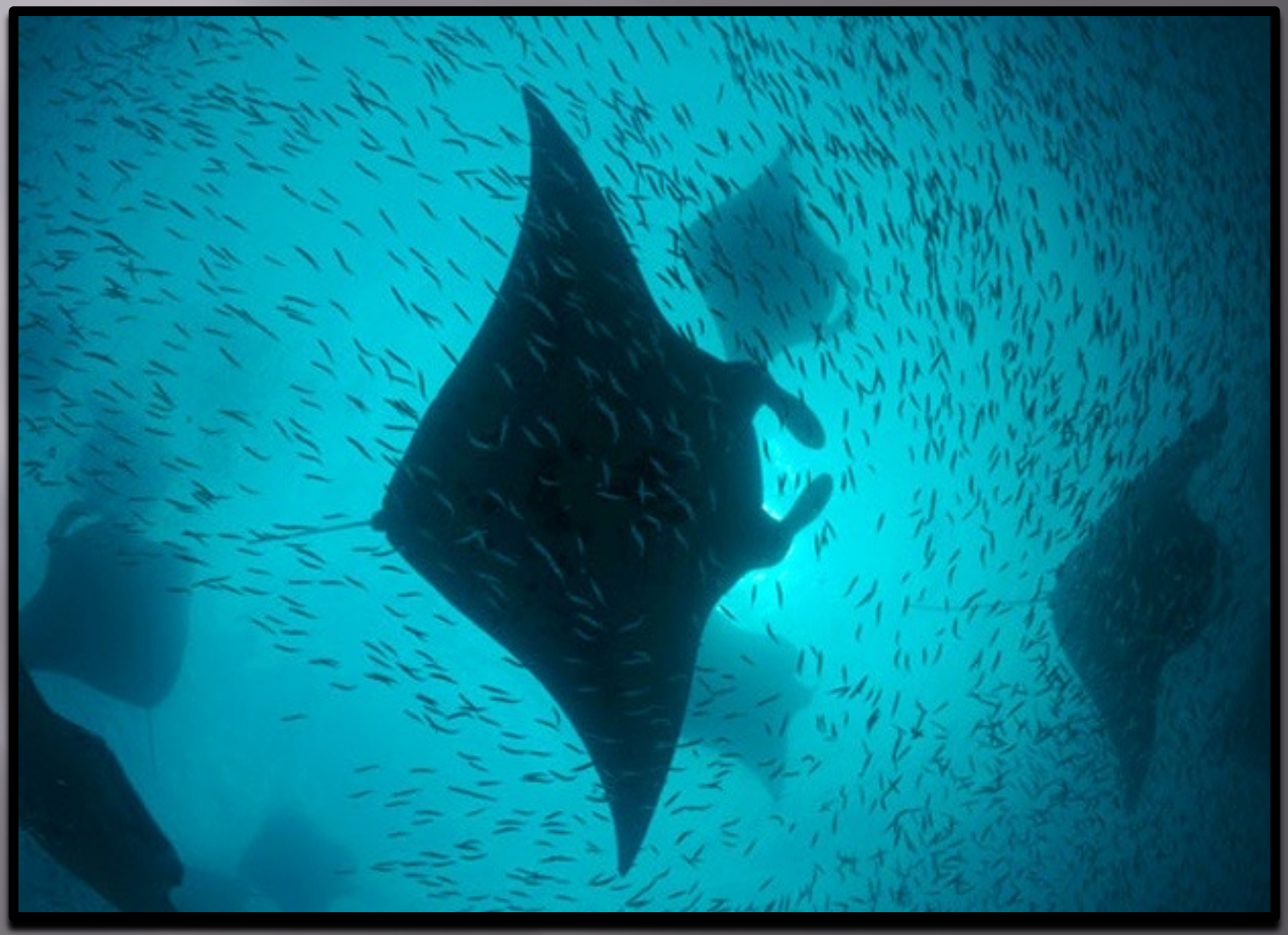


Chest Tube Placement

Once The Lungs are Stabilized…

You can treat with hyperbarics

Decompression Sickness



Definition of DCS

- A DECREASE in ambient pressure coupled with an excess of dissolved inert gas
- Promotes gas release out of solution
- Bubbles form in tissues and/or blood in volumes sufficient to interfere with function

Definition of DCS

Decompression sickness arises in compressed gas divers, aviators, and astronauts when bubbles form in blood and / or in tissues, during or after a decrease in environmental pressure

Who is at Risk?

Diagnosing DCS

- History of a provocative dive profile
- Proximity of symptom onset to time of decompression
- Clinical signs and symptoms

What's Provocative?

- Can be difficult to determine
- Multilevel dives vs. tables
- 120 Rule
- Suspicion increases when:
  - Dives >60fsw
  - Air vs. EAN
  - Short surface intervals (< 1 hour)
  - Repetitive dives
  - Reverse profiles

Information Gathering

- Dive History
  - Brief summary usually adequate
  - Obvious problems important e.g. missed deco
- History of symptoms
  - Latency, nature, progression
- Examination
  - No problem with “field neuro exams” but…
  - NEVER use results to exclude the diagnosis

Manifestations of DCS

- **Onset within 1 hour in 50% of cases**
- **Onset within 6 hours in 90% of cases**
- **Onset within 24 hours in 99% of cases**

Beyond 24-36 Hours, the Diagnosis of DCS Becomes Questionable!

DCS Symptoms

- Skin rash/itch
- Joint pain
- Numbness/tingling
- Paralysis
- Confusion
- Weakness
- Trunk pain
- Extreme fatigue
- Visual changes
- Shock
- Chokes

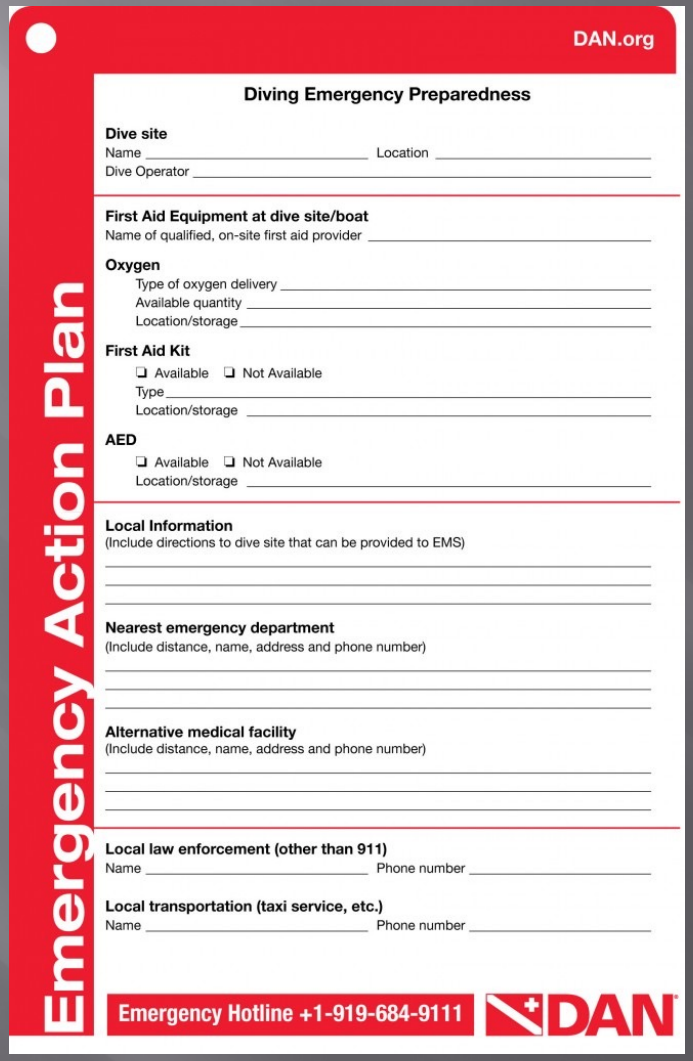
DCS Triage

- **Early Presentation**
  - Sx often severe and likely to worsen
  - Initiate 1st Aid
  - Call 911
  - Call DAN
  - Goal: transportation to nearest ED
- **Late Presentation**
  - Sx often mild or equivocal
  - History +/- examination
  - Discussion / evaluation with diving physician

Overview of Consensus Guidelines Pre-Hospital DCI Management

- 1. PROCEDURAL CONSIDERATIONS
  - Divers and dive operations should have contact details for and a rapid and reliable means of communicating with diving emergency services and local emergency services in order to obtain advice about initial management, regional retrieval systems and treatment facilities.
- In our region, this has implications depending on your distance to a treating recompression facility. The current recompression facilities need to **ALWAYS** be coordinated through Divers Alert Network as they have the operational listing. Ensure that your boat has an **Emergency Action Plan** in place prior to dive operations.

Emergency Action Plan



DAN.org

Emergency Action Plan

Diving Emergency Preparedness

Dive site
Name _____ Location _____
Dive Operator _____

First Aid Equipment at dive site/boat
Name of qualified, on-site first aid provider _____

Oxygen
Type of oxygen delivery _____
Available quantity _____
Location/storage _____

First Aid Kit
❑ Available ❑ Not Available
Type _____
Location/storage _____

AED
❑ Available ❑ Not Available
Location/storage _____

Local Information
(Include directions to dive site that can be provided to EMS)
_____
_____
_____

Nearest emergency department
(Include distance, name, address and phone number)
_____
_____
_____

Alternative medical facility
(Include distance, name, address and phone number)
_____
_____
_____

Local law enforcement (other than 911)
Name _____ Phone number _____

Local transportation (taxi service, etc.)
Name _____ Phone number _____

Emergency Hotline +1-919-684-9111 DAN

PROCEDURAL CONSIDERATIONS

- The current facilities treating DCI on the Gulf Coast are:
  - AdventHealth Orlando

601 East Rollins Street
Orlando, Florida
407-303-6611

  - Blake Medical Center

2020 59th Street West
Bradenton, Florida
941-792-6611

  - Springhill Medical Center

3719 Dauphin Street
Mobile, AL
251-344-9630

PROCEDURAL CONSIDERATIONS

- All dives who become "unwell" after diving should be discussed with a dive medicine physician as soon as possible.
  - The best way to accomplish this is to report to your NEAREST emergency room for evaluation. Then contact the Divers Alert Network Emergency Hotline at 919-684-9111.

Neuro Checks Pre and Post

NEUROLOGICAL ASSESSMENT

Vital Signs: Pulse rate____/Min Respirations____/Min Blood pressure____/____

MENTAL FUNCTION

Consciousness:
- ❑ Alert
- ❑ Verbal
- ❑ Painful
- ❑ Unresponsive

Orientation:
- ❑ Person (what is your name?)
- ❑ Place (where are you?)
- ❑ Time (estimate what time it is?)

Ability to follow commands: Ask the diver to "Stick out your tongue and close your eyes." ❑ Yes ❑ No

Expression: Say "red, white and blue" or "no ifs, ands or buts." ❑ Yes ❑ No

Name 3 objects (e.g., comb, mask, scuba cylinder): ❑ Yes ❑ No

Read and interpret a sentence: ❑ Yes ❑ No

Example: "The small boy walked to the lake with a large dog."

Judgment:
Why are you here?
❑ Yes ❑ No

Memory: 3 items/3 minutes
Repeat 3 objects identified earlier
❑ Yes ❑ No

Calculations: (circle misses) 93, 86, 79, 72, 65, 58, 51, 44, 37, 30, 23, 16, 9, 2
Able to complete? ❑ Yes ❑ No

Abstract reasoning/proverbs: Interpret a proverb such as "A bird in the hand is worth two in the bush." Or "A stitch in time, saves nine."
Could the diver explain the proverb? ❑ Yes ❑ No

CRANIAL NERVES

EYES: Forward Left Right Up Down Nystagmus (eye twitching): ❑ Yes ❑ No
Circle any direction the diver cannot look.
FACE: Close eyes and smile. HEARING: Symmetrical ; > 1 foot ❑ Yes ❑ No
Is the face symmetrical? ❑ Yes ❑ No
LIGHT TOUCH: Forehead L ❑ R ❑ Cheek L ❑ R ❑ Jaw L ❑ R ❑ Chin L ❑ R ❑
Identify any area where the diver identifies altered sensation.

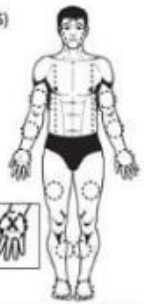
MOTOR FUNCTION

Grading scale: No movement (0), Movement but weak (3), Normal (5)

Arms:	Shoulders	L___ R___	Legs:	Hip flexors	L___ R___
	Biceps	L___ R___		Quadriceps	L___ R___
	Triceps	L___ R___		Hamstrings	L___ R___
	Finger spread	L___ R___		Foot (up)	L___ R___
	Grip strength	L___ R___		Foot (down)	L___ R___

SENSORY FUNCTION

Shade in any areas on the figure at right with decreased sensation using the symbols below.
LIGHT TOUCH: X PIN: P BOTH: B



COORDINATION AND BALANCE

WALK: ❑ Normal ❑ Wobbly ❑ Unable to complete
FINGER-NOSE-FINGER: Able to complete? ❑ Yes ❑ No

COMMENTS:_____

DAN DIVERS ALERT NETWORK 1-919-684-4DAN

On-Site Neurological Assessment for Divers

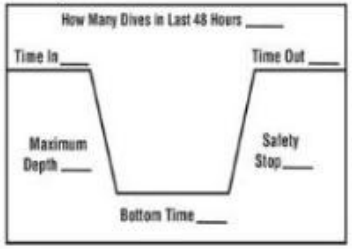
HISTORY

Last Name: _____ First Name:_____ MI: ____
DATE: _____ TIME (hh:mm):_____ Completed by:_____

Symptoms began:
- ❑ Before dive
- ❑ During descent
- ❑ At bottom
- ❑ During ascent
- ❑ At deco/safety stop
- ❑ On surface

What symptoms are you feeling?
- ❑ Numbness and tingling Location_____
- ❑ Dizziness ("light headedness")
- ❑ Vertigo (spinning)
- ❑ Ringing or buzzing in ear
- ❑ Decreased hearing
- ❑ Rash and itching
- ❑ Difficulty breathing
- ❑ Visual disturbance
- Other _____
- Other _____
- Other _____

History of last dive



Breathing gas
- ❑ Air
- ❑ Nitrox ____%
- ❑ TriMix ____O2% ____He% ____N2%
- ❑ Other _____

Unusual features
- ❑ Rapid ascent
- ❑ Missed decompression
- ❑ Out of air ascent
- ❑ Difficulty equalizing

Dive planning
- ❑ Dive computer _____
- ❑ Dive table _____
- ❑ Other _____

Pain

Where? _____
Does it change with movement? ❑ Yes ❑ No Rate the pain: 0 1 2 3 4 5 6 7 8 9 10

Other conditions

Nausea, vomiting? ❑ Yes ❑ No Able to urinate? ❑ Yes ❑ No ❑ Unsure
Difficulty walking? ❑ Yes ❑ No Difficulty with balance? ❑ Yes ❑ No
Arm/leg weakness? ❑ Yes ❑ No

Pre-existing conditions that might influence findings

_____

From 'observer' (e.g., dive buddy, companion)

Confirm profile information with an observer and list additional or conflicting information.

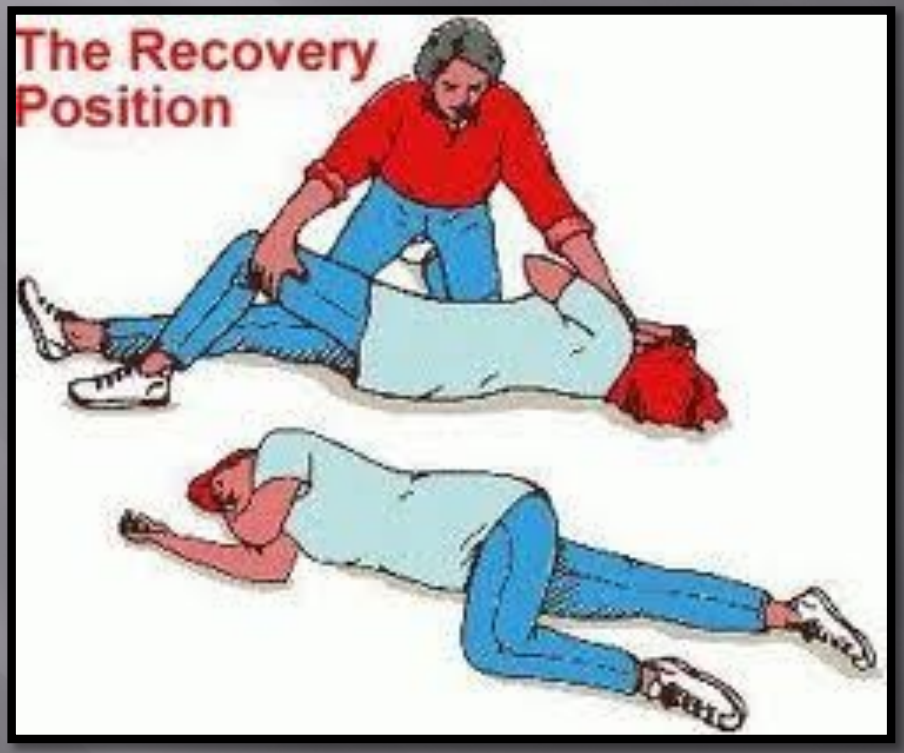
_____
_____
_____
_____

DAN DIVERS ALERT NETWORK 1-919-684-4DAN

FIRST AID PROCEDURES

- Surface level oxygen administered to as close as 100% as possible as soon as the onset of symptoms are noted.
  - O2 provider courses are highly recommended.
- A system capable of the administration of a high percentage of inspired oxygen and a sufficient oxygen supply for an evacuation scenario. (Use of enriched air is better than no increase in the fraction of oxygen at all.)
- A horizontal position is encouraged. A side lying recovery needs to be utilized if the patient is unconscious.

Recovery Position



100% Oxygen Administration

Theoretical Benefits

- **Accelerates inert gas elimination**
- **Improves oxygenation of injured tissue**
- **Accelerates N_2 bubble resolution *in vivo***
  Hyldegaard et al. Undersea Biomed Res 1991;18:361-71
- **Faster response to recompression and smaller numbers of recompressions in human divers**
  - **No difference in final outcome!**
    Longphre et al. Undersea Hyperb Med 2007;34:43-9

Courtesy of Dr. Simon Mitchell

How to Give 100% Oxygen

Carry Enough of It!!

Provide a Therapeutic Dose!

- **Demand valve**
- **NRB mask with oxygen flowing at ~ 15LPM**

FIRST AID PROCEDURES

- Oral hydration is recommended. If the patient is not fully conscious , oral fluids should be avoided. Fluids should be non-carbonated, non-caffeinated, nonalcoholic.
  - Qualified and skilled responders should initiate an intravascular or intraosseous access. Provide non-glucose isotonic crystalloid solution.
  - Keep the diver thermally comfortable.
    - Avoid hyperthermia
    - Avoid exposure to sun, unnecessary activity or excessive clothing.

Mild or Marginal vs Type II DCS

- Signs and Symptoms for "Mild" DCS include:
- Musculoskeletal pain (limb pain)
- Rash
- Constitutional symptoms
  - Fatigue
  - Cutaneous sensory changes (niggles)
  - Subcutaneous swelling (lymphphatic DCI)
- Note: Severity of pain has little prognostic significance

  of classification of symptoms

SAFE DIVING TIPS

- Be medically fit for diving
- Be physically fit for diving
- Don't dive if you are feeling unwell
- Be well hydrated
- Be well insulated
- Avoid deep dives
- Reduce depths during multi-level dives
- Ascend slowly
- Do safety stops
- Minimize exercise during and after diving
- Maximize Surface Intervals
- Minimize repetitive diving
- Report unusual symptoms
- Dive with a buddy
- Dive within your training and experience
- Ensure all equipment is well maintained and in good working order

Springhill Medical Center

Center for Wound Care and Hyperbaric Medicine

Main Hospital Number (251) 344-9630

3719 Dauphin Street P.O. Box 8246 Mobile, AL 36689

Phone 251-460-5259/Fax 251-345-1556

Facility: (2) Sigma II Dual Place, Max 3 ATA

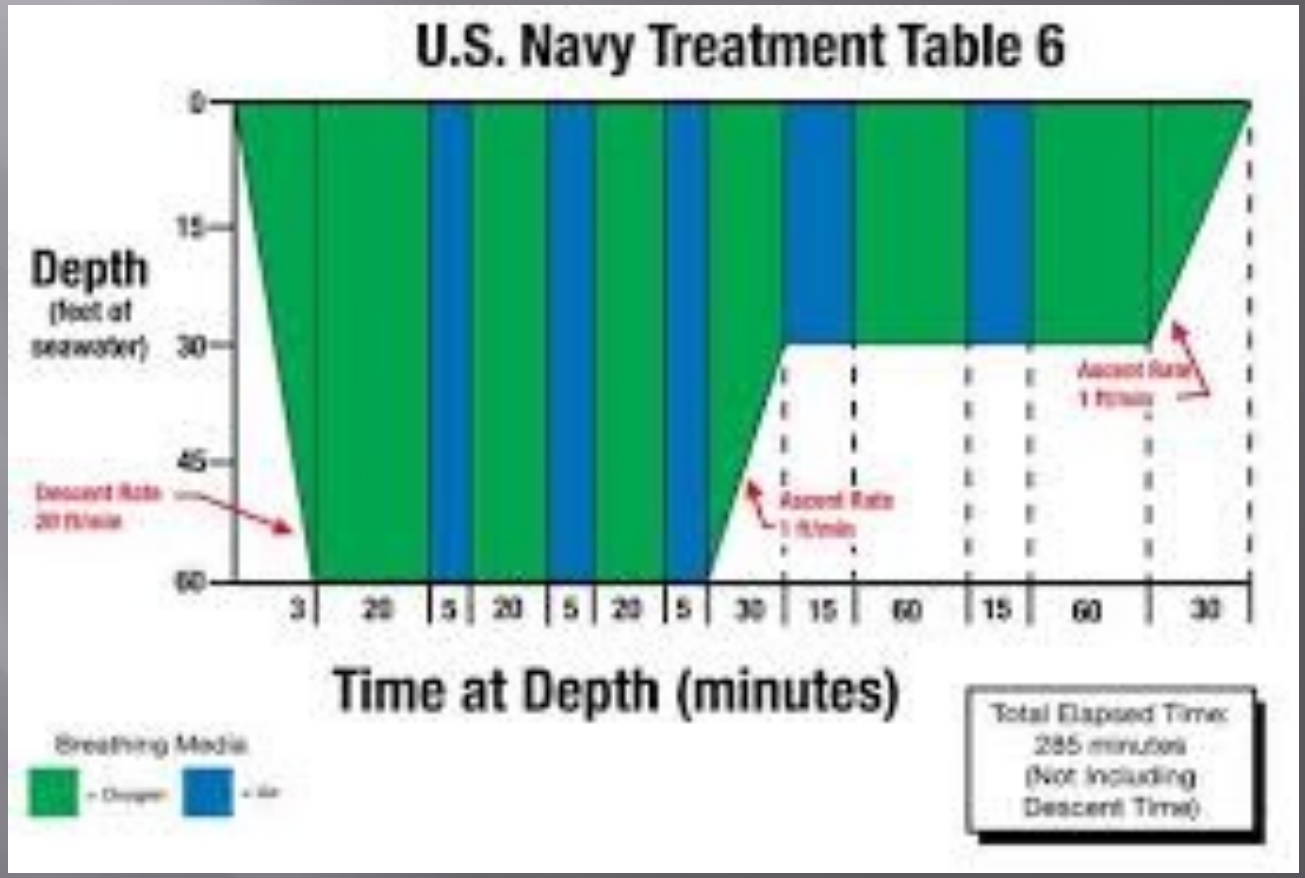
Ventilator, Invasive Monitoring, EKG and IV's

Accredited by UHMS

Helicopter Coordinates: N 30.40.59 W 88.07.32

AFTER HOURS OF 0800-1630 CALL THE MAIN HOSPITAL NUMBER

TREATMENT TABLES used in the treatment of DCI

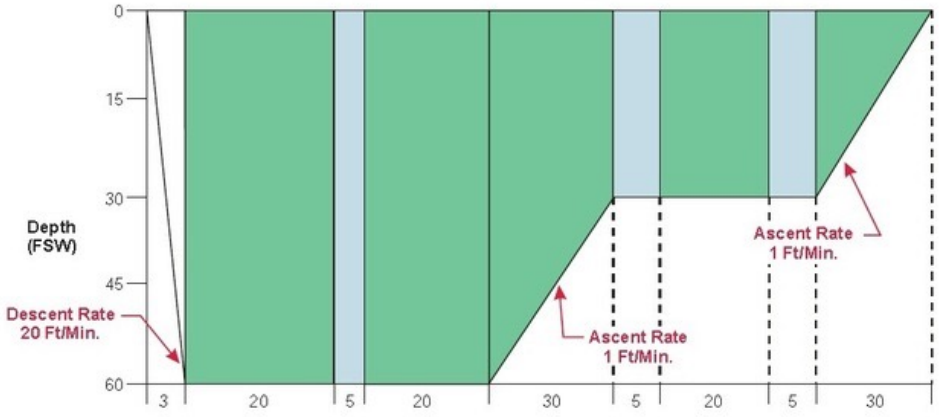


TREATMENT TABLE 5

Treatment Table 5

1. Descent rate - 20 ft/min.
2. Ascent rate - Not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time on oxygen begins on arrival at 60 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 20-7.11.1.1)
5. Treatment Table may be extended two oxygen-breathing periods at the 30-foot stop. No air break required between oxygen-breathing periods or prior to ascent.
6. Tender breathes 100 percent O_2 during ascent from the 30-foot stop to the surface. If the tender had a previous hyperbaric exposure in the previous 18 hours, an additional 20 minutes of oxygen breathing is required prior to ascent.

Treatment Table 5 Depth/Time Profile



TREATMENT TABLE 9