Dive Training for Supervisors

Intended Audience:

Supervisors of Milagro Dive Operations

Gus Sinnis

P-23 / LANL

Course Outline

- Diving Physics
  - Pressure, Diffusion
- Diving Physiology
  - Cardiopulmonary System
  - The Ear
- Diving Injuries
  - The Bends
  - AGE: Arterial Gas Embolism
- Understanding Dive Tables
  - Repetitive Dives
  - Diving at Altitude

Diving Physics

- PV = nRT
  - 10 m of H_2O ~ 1 atm
- Air = 20.8 % O_2 + 79 % N_2 + Contaminants
  - pp O_2 = 0.2 x 14.7 ~ 3 psi O_2
  - pp N_2 = 0.8 x 14.7 ~ 12 psi N_2
- Absorption rate is proportional to difference in partial pressure (tissue:ambient)
- Specific heat of H_2O = 25 x C_{air}
  - Body loses heat 25 times faster in water

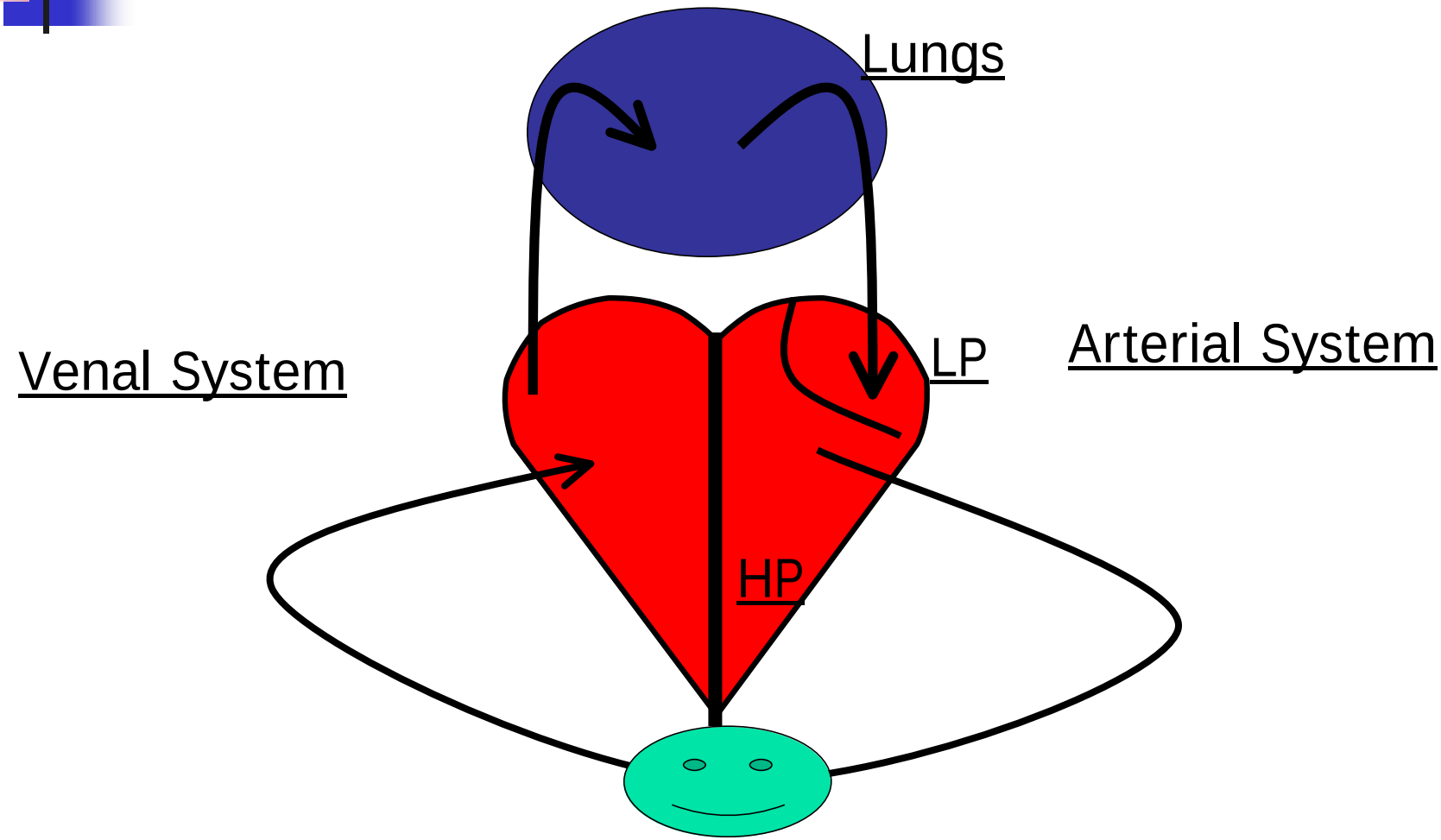
Breathing at Depth

- Equilibration
  - internal pressure = external pressure
- At 10m depth
  - pp O_2 = 6 psi
  - pp N_2 = 24 psi
- Breathe at depth - hold breath - rise to surface - air expands! Do Not Do!

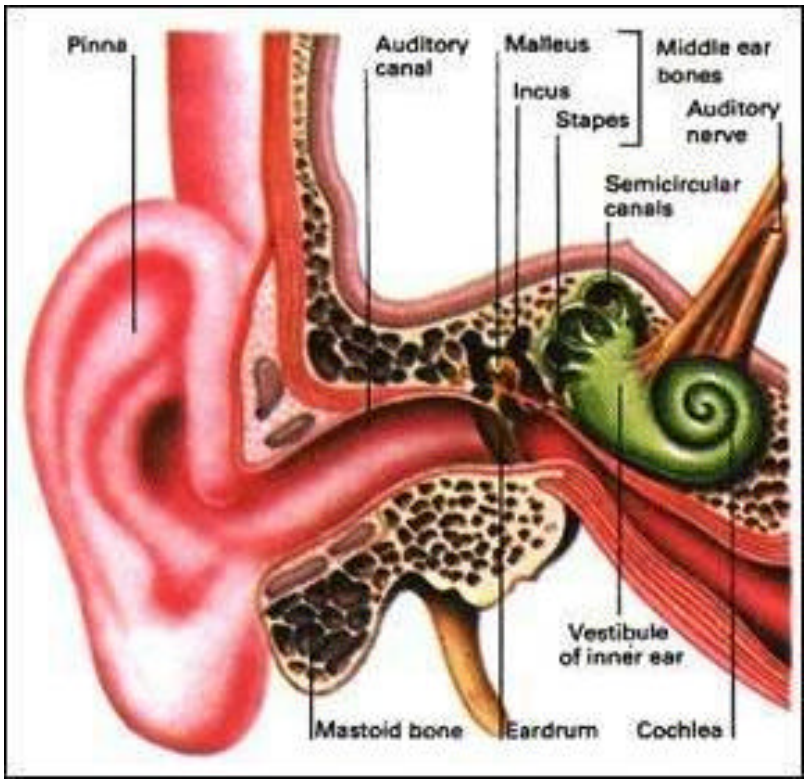
Diving Physiology (Basics)

- 14 pints of blood in body
- Heart pumps blood to organs
- Blood transfers O_2 to organs
  - Perfusion: distribution of O_2 to tissues
- Arteries take blood from heart (high O_2)
- Veins bring blood to heart (low O_2)
- Lungs inject O_2 into blood
  - Alveoli surrounded by venal & arterial capillaries. Diffusion equalizes pp O_2/N_2 on each side of alveoli.

The Cardiopulmonary System



The Ear



- Must Equalize pressure in ear
- Alternobaric Vertigo
  - Sudden pressure change
  - Lose orientation
- Round or Oval Window Rupture
  - Pain, blood, hearing loss

Diving Injuries I: The Bends

- At depth organs & tissues absorb N_2
  - Takes ~days to saturate
- At surface N_2 leaves tissues (pp N_2)
- Lungs screen bubbles and N_2
- But if N_2 out gasses too quickly or is too much to screen, bubbles form and roam body.

The Bends (cont'd.)

- Symptoms depend on where bubbles emerge.
  - In joints = pain
  - In spinal cord = sensory/motor dysfunction
  - In lungs = difficulty breathing
  - In brain = impairment of hearing, speech, thought. Loss of consciousness. Paralysis.

Bends: Signs and Symptoms

- Common Signs & Symptoms
  - Numbness, Headache, Pain
  - Dizziness, Nausea, Weakness
  - Unusual fatigue, Difficulty walking
- Other Signs & Symptoms
  - Breathing difficulty, itching, rash, bladder/bowel problems, personality change, speech problems, hearing loss, convulsions, coughing blood, paralysis.

Diving Injuries II: AGE

- AGE: Arterial Gas Embolism
  - Pressure differential = 4’ of H_2O can burst alveoli.
  - Bubble goes to brain or heart
  - Bubble blocks artery/capillary in brain
  - Bubble stops blood flow to affected region

Diving Injuries III: Pulmonary Barotrauma

- Air bubbles can get other places
  - Under sternum
  - Into neck
- Signs & Symptoms
  - Difficult breathing
  - Chest pain
  - Cyanosis
  - Swelling of neck
  - Crackling under skin
  - Voice changes

Diving Injuries IV: Other

- Nitrogen narcosis (rapture of the deep)
  - Excessive N_2 level in blood has effects similar to laughing gas (nitrous oxide).
  - Occurs at depths of 80-120’
- Oxygen poisoning
  - pp O_2 = 1.6 (1.4) atm is toxic (work diving)
  - Can not dive > 70 m on air
  - Mixed gas diving – Nitrox (elevated O_2), tri-gas (He, N_2, O_2), Heliox (He, O_2)

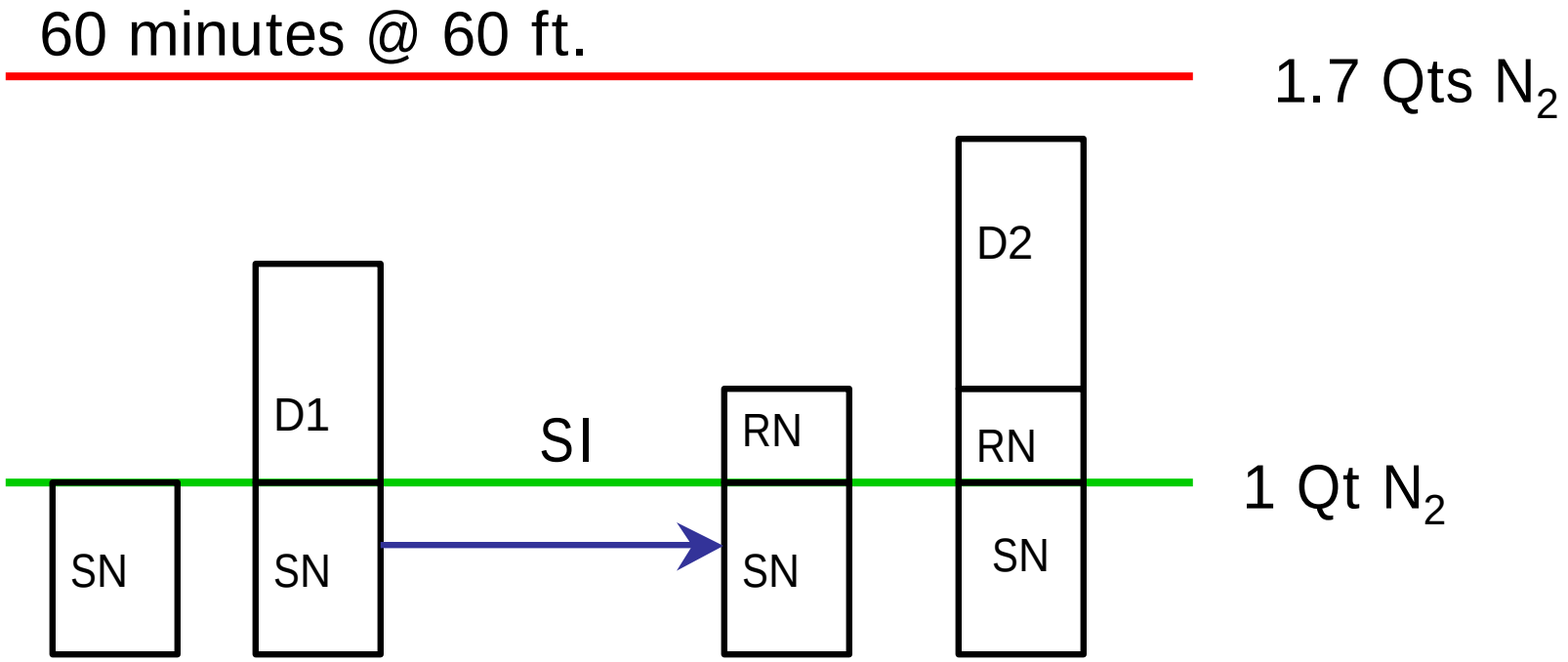
Treatment of Diving Injuries

- 100% O_2 100% O_2 100% O_2 100% O_2
  - Body burns O_2 (does not burn N_2)
  - Higher pp O_2 displaces N_2 in bubble DIFFUSION
  - Bubble shrinks.
- Emergency room for diagnosis
- Recompression

The Navy Dive Tables

- Use dive tables to <u>reduce the risk</u> of DCS (bends)
- CAUTION!! DCS depends on physical condition of diver, dive conditions, and N_2 level in tissue.
- 5-10% of Navy divers ***will*** get bent diving within the limits of the Navy tables.
- Use safety stop (3-5 mins @ 10' *EDSL*)

Navy Dive Tables (Cont'd)



SI: Surface Interval

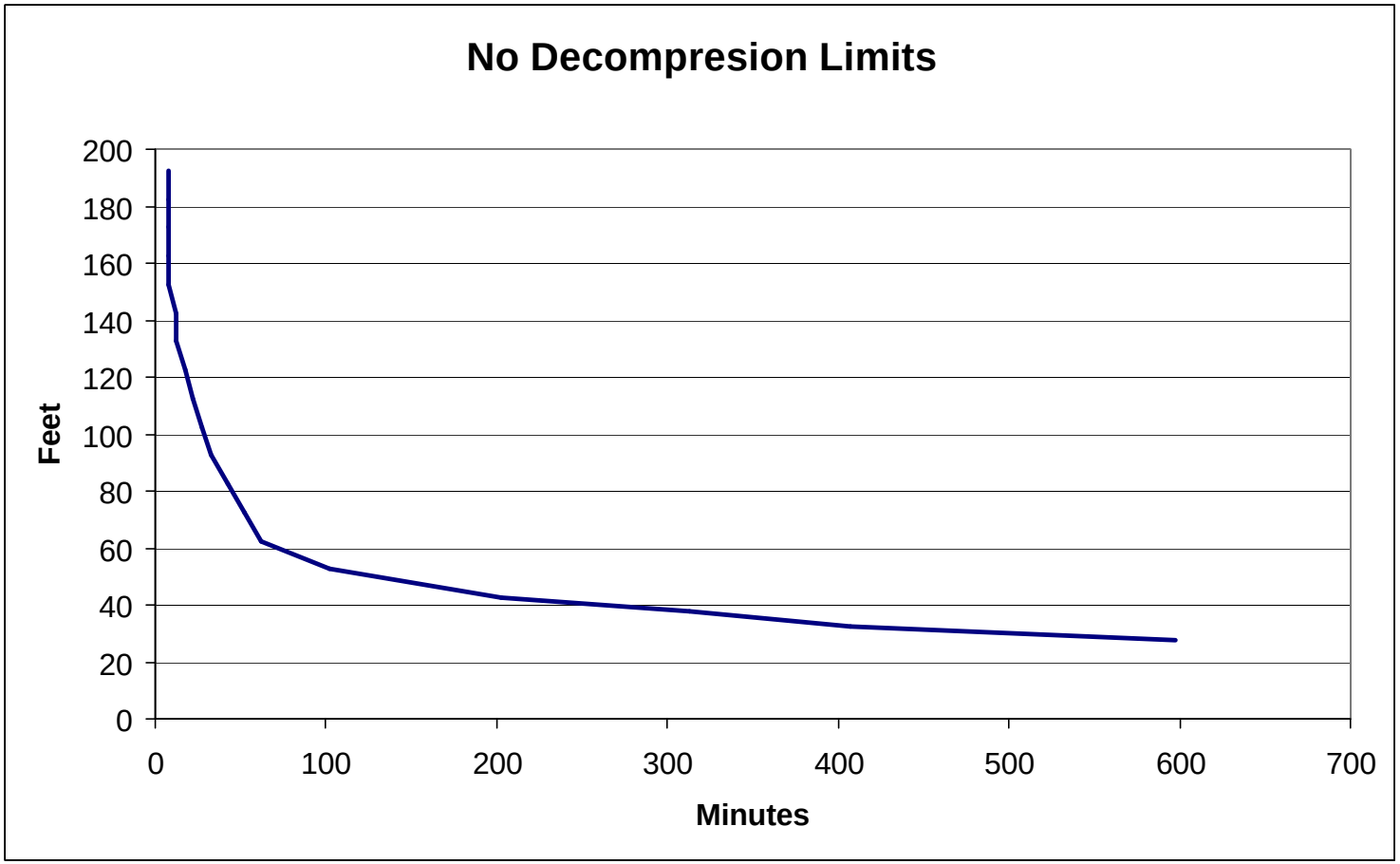
RN: Residual N_2

SN: Surface N_2

Navy Dive Tables (Cont'd)

- Total Bottom Time (includes descent NOT ascent). Use TBT in tables.
- ALWAYS ROUND UP (21 = 30)!
- 3 Tables
  - NDL (No Decompression Limits) & Repetitive Group Designation Table
  - Surface Interval Table
  - RNT (Residual Nitrogen Time) Table

No Decompression Limits



Navy Tables: Example

- Diver dives to 41’ for 51 minutes
  - Group designation is H
- Diver stays on surface for 25 minutes
  - Group designation is H
- Diver dives to 53’
  - RNT is 52 min.
- How much time can diver spend @ 60’ ?
  - 8 minutes

Diving at Altitude

- Decreased pressure = faster outgassing
- How to compensate?
  - If: $$\frac{d(gas)}{dt} = kf(N_2)\frac{p_{N_2}(tissue)}{p_{N_2}(ambient)}$$
  - Keep $d(gas)/dt$ as a sea level dive

$$\frac{Depth(altitude)}{Depth(sealevel)} = \frac{p(sealevel)}{p(altitude)}$$

Diving at Altitude (Cont'd)

- So use the same dive tables
- Correct the depth to reflect the pressure differential between depth and ambient pressure.
- Example: diving at 8650' ASL
  - P(SL)/P(8650) = 1.33
  - Equivalent Depth (EDSL)= 1.33 x Altitude Depth

Diving at Altitude (Cont'd)

- Flying after diving – treat like diving at altitude.
  - Recommend wait 12-24 hrs after dive to fly
- Complication – Arriving at altitude and diving
  - Tissues are already out gassing upon arrival to dive sight.
  - Treat as a repetitive dive
  - Ascent from LA – B diver upon arrival to Fenton

Responsibilities of Supervisors

- Be aware of divers
  - Dive times (within AA NDLs)
  - Physical condition
- Organize dive site
  - Does everyone know their job?
  - Comms working?
  - Emergency personnel reachable?
- Ensure diver's safety

Accident Prevention

- Best time to prevent an accident is

  BEFORE A DIVE

- Warning signs
  - Stress
  - Pre-dive look for
    - Illness or injury
    - Equipment problems (broke or missing)
    - Hesitation, stress. Any sign diver does not want to dive
  - Entry look for
    - Improper technique
    - Equipment rejection, high treading
    - Hesitation going under (holding buddy etc.)