NOAA DIVING PROGRAM

DIVING MEDICAL TECHNICIAN COURSE

December 12 - 16, 2016

NOAA Diving Center
Seattle, WA

National Oceanic and Atmospheric Administration
Diving Medical Technician Course
Seattle, Washington

Day 1	**12-Dec-16**	
8:00 — 8:30	Welcome/logistics/intro	Montgomery
8:30 — 9:30	Gas Laws	Gordon
9:30 — 9:40	Break	
9:40 — 10:20	Atmospheric and Hydrostatic Pressure	Gordon
10:20 — 10:30	Break	
10:30 — 11:45	Physiology & Pathophysiology of Immersion	Dulaigh
11:45 — 12:45	Lunch	
12:45 — 13:45	Intro to PVHO and Chamber Operations	Hileman
13:45 — 13:55	Break	
13:55 — 14:30		
14:30 — 15:30	Inert Gas Narcosis & O2 Toxicity	Montgomery
15:30 — 15:35	Break	
15:35 — 16:35	Non-pulmonary Barotrauma	Dulaigh

Day 2	**13-Dec-16**	
7:30 — 9:30	Neurologic Exams Lecture & Skills	Montgomery
9:30 — 9:40	Break	
9:40 — 10:30	NG Tube and Foley Cath Lecture & Skills	Dulaigh
10:30 — 10:40	Break	
10:40 — 11:30	Chest Decompression Lecture & Skills	Montgomery
11:30 — 12:30	Lunch	
12:30 — 15:00	Chamber ops with skills - 60' dives	All
15:00 — 16:00	U.S. Navy Decompression Tables Review	Hilman

Day 3	**14-Dec-16**	
7:30 — 8:30	Pathophysiology of Decompression	Dulaigh
8:30 — 8:40	Break	
8:40 — 9:30	Acute Dysbaric Disorders	Dulaigh
9:30 — 9:40	Break	
9:40 — 11:15	DCS Management & Treatment Tables	Dulaigh
11:15 — 12:15	Lunch	
12:15 — 15:00	165’ Chamber Dive with Neuro Skills Practice	All
15:00 — 16:00	Medication Administration Lecture & Skills (IM &SC)	Montgomery

Day 4 **15-Dec-16**

7:30 — 9:00	Intravenous & Interosseous Access Lecture & Skills	Montgomery
9:00 — 9:10	Break	
9:10 — 11:00	Airway Management/Suction Lecture & Skills	Montgomery
11:00 — 12:00	Lunch	
12:00 — 15:00	Chamber ops with skills - 60' dives	All
15:00 — 16:00	Thermal Considerations	Jeremiah

Day 5 **16-Dec-16**

7:30 — 8:30	Medications, Substances, and Diving	Dulaigh
8:30 — 8:40	Break	
8:40 — 10:00	Hazardous Marine Life Accidents	Jeremiah
10:00 — 10:10	Break	
10:10 — 11:00	Professional Affairs (CEUs, clinical, & other resources)	Montgomery
11:00 — 12:00	Lunch	
12:00 — 14:30	Exam & Review	Montgomery
14:30 — 15:00	Graduation/Evaluation/Closure	All

Boyle's Gas Law

Presented by the NOAA Diving Center
Seattle, Washington

Global View

- Boyle's Law definition
- Relevance of Boyle's Law to diving
- Boyle's Law formula
- Mathematical calculations
- Key Points

Introduction

- **Need and value:** Now that you understand how to calculate units of pressure, you are ready to learn to do advanced level calculations. You will learn how to calculate pressure/volume equations.
- **Effect:** By the end of the course you should be able to calculate in the field the correct solution to any dive physics problem that involves pressure and volume.

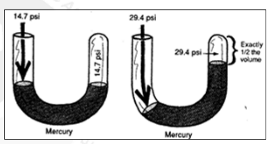
Boyle's Law

- Definition: At constant temperature, the volume of a gas varies inversely with absolute pressure, while density varies directly with absolute pressure
- Relevance: Mechanical effects of pressure (e.g., buoyancy issues, barotrauma injuries, air-filled spaces in the human body)

As pressure increases, volume decreases, and vice-versa

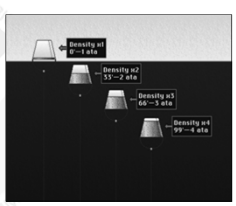
Pressure/Volume Relationship

- Robert Boyle (1660) did early experiments with pressure and volume relationships
- Determined that doubling the pressure on a gas reduced volume of gas by one-half



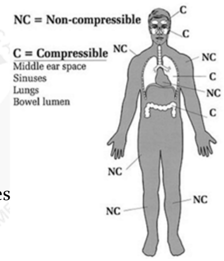
Direct Effects of Pressure - 1

Depth	Pressure	Volume
0'	1 ATM	1
33'	2 ATA	1/2
66'	3 ATA	1/3
99'	4 ATA	1/4



Direct Effects of Pressure - 2

- Bone, muscle, blood and solid organs: non-compressible
  - Not affected by the pressure changes at depth
- Lungs, middle ears, sinuses nasal passages, hollow organs, tooth cavities: compressible
  - Affected by the pressure changes at depth



Need to Knows

33 fsw = 1 atm = 14.7 psi
1 psi = 0.432 fsw

34 ffw = 1 atm = 14.7 psi
1 psi = 0.445 ffw

Boyle's Law Formula

- $P_1V_1 = P_2V_2$

  P_1 = Starting Pressure (ATA)
  V_1 = Starting Volume
  P_2 = Ending Pressure (ATA)
  V_2 = Ending Volume

Note: Always use absolute pressure when working Boyle's gas law problems

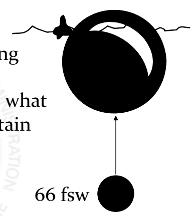
Formula Rules

For correct calculations:

1. Determine known and unknown variables
2. Set up your formula
3. Express variables in units (always use absolute pressures and temperatures)
4. Substitute variables into formula and solve
5. Cancel like units
6. Express answer in units specified: psig, psia, fsw, ATA

Calculating Boyle's Law - 1

- Example #1:
  - A diver releases a balloon containing 0.25 cf of air at a depth of 3 ATA. Assuming no temperature change, what volume of gas will the balloon contain when it reaches the surface?



What is the unknown?

Calculating Boyle's Law - 1

Calculating question #1:

- Determine variables:
  - P_1 = Start Pressure = 3 ATA
  - P_2 = End Pressure = 1 ATA
  - V_1 = Start Volume = 0.25 cf
  - V_2 = End Volume = ? cf
- Set up formula to solve for V2

Use the Formula Rules as a check list

Calculating Boyle's Law - 1

Answer to question #1:

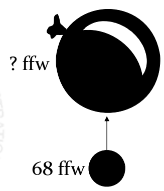
$$V_2 = \frac{P_1 V_1}{P_2} = \frac{3\ \text{ATA} \times 0.25\ \text{cf}}{1\ \text{ATA}} = \frac{0.75\ \text{cf}}{1} = \mathbf{0.75\ cf}$$

Note: Reducing pressure to 1/3 of initial force tripled the volume

Calculating Boyle's Law - 2

Example #2:

If a balloon contains 0.4 cf of air at a depth of 68 ffw, at what depth will the volume of the balloon be 1.0 cf?



What is the unknown**?**

Calculating Boyle's Law - 2

Calculating example #2:

- Determine variables:
  - P_1 = Start Pressure = $\frac{(68\ \text{ffw} + 34\ \text{ffw})}{34\ \text{ffw}} = 3$ ATA
  - V_1 = Start Volume = 0.4 cf
  - V_2 = End Volume = 1.0 cf
  - P_2 = End Pressure = ? ffw
- Set up formula to solve for P_2

Apply the Formula Rules

Calculating Boyle's Law - 2

Answer to question #2:

$$P_2 = \frac{P_1 V_1}{V_2} = \frac{3\ ATA \times 0.4\ cf}{1\ cf} = \frac{1.2\ ATA}{1} = 1.2\ ATA$$

Convert ATA to depth...

1.2 ATA - 1.0 ATM = 0.2 ATM x 34 ffw = **6.8 ffw**

Calculating Boyle's Law - 2

OR

$$P_2 = \frac{P_1 V_1}{V_2} = \frac{44.1\ psia \times 0.4\ cf}{1\ cf} = \frac{17.64\ psia}{1}$$

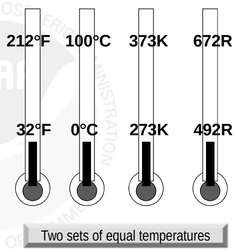
$$17.64\ psia - 14.7\ psi = \frac{2.94\ psig}{0.432\ psig/ffw} = \mathbf{6.8\ ffw}$$

Charles and Gay-Lussac Gas Laws

- Temperature scales and conversions
- Definition of Charles' Law
- Relevance of Charles' Law to diving
- Charles' Law formula
- Mathematical calculations using Charles' Law
- Definition of Gay-Lussac's Law
- Relevance of Gay-Lussac's Law to diving
- Gay-Lussac's Law formula
- Mathematical calculations using Gay-Lussac's Law

Absolute Temperature

- Temperature scales:
  - Fahrenheit (F)
  - Celsius (C)
  - Rankine (R)
  - Kelvin (K)
- Absolute temperature conversions:
  - °F = (9/5 X °C) + 32
  - °C = 5/9 X (°F - 32)
  - Rankine = °F + 460
  - Kelvin = °C + 273



Temperature Conversion – 1

- Question #1: 70 degrees F. = ____ degrees C?
  - Formula: °C = 5/9 X (°F - 32)
- Answer
  - °C = 5/9 X (°70 - 32)
  - °C = 0.556 X 38
  - °C = 21.13

Temperature Conversion - 2

- Question #2: 17 degrees C. = _____ degrees K?
  - Formula: Kelvin = °C + 273
- Answer
  - Kelvin = 17 °C + 273
  - Kelvin = 290 °

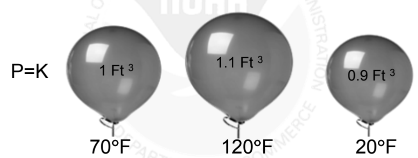
Charles' Law

- Definition: At a constant pressure, the volume of a gas varies directly with absolute temperature
- Relevance: Effects of temperature on air-filled spaces (e.g., buoyancy issues, lift bags)

As temperature increases, volume increases, and vice-versa

Effects of Temperature: Charles

- As temperature increases, volume increases
- As temperature decreases, volume decreases



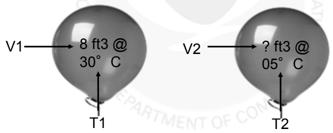
Charles' Law Formula

- $\frac{V_1}{V_2} = \frac{T_1}{T_2}$
  - V_1 = Starting volume
  - T_1 = Starting temperature (abs)
  - V_2 = Ending Volume
  - T_2 = Ending temperature (abs)

Note: Always use absolute temperature when working Charles' gas law problems

Calculating Charles' Law – 1a

- Example #1:
  - A balloon contains 8.0 cf of air at a temperature of 30°C. What will the volume of air be in the balloon when the temperature of the air inside is 5°C?



Calculating Charles' Law – 1b

- Calculating example:
  - Determine factors:
    - V_1 = Start Vol. = 8.0 cf
    - T_1 = Start Temp. = 30°C. + 273 = 303 K
    - V_2 = End Volume = ?cf
    - T_2 = End Temp. = 5°C. + 273 = 278 K
  - Select formula, transpose, and solve for V_2

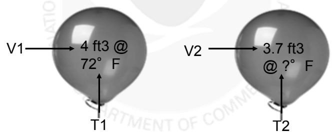
Calculating Charles' Law – 1c

- Answer to example #1:

$$V2 = \frac{V1T2}{T1} = \frac{8.0\ cf \times 278\ \cancel{K}}{303\ \cancel{K}} = \frac{2{,}224\ cf}{303} = 7.34\ cf$$

Calculating Charles' Law – 2a

- Example #2:
  - A balloon contains 4.0 cf of air at a temperature of 72°F. What will the temperature be when the volume of the balloon is 3.7cf **?**



Calculating Charles' Law – 2b

- Calculating example:
  - Determine factors:
    - V_1 = Start Vol. = 4.0 cf
    - T_1 = Start Temp. = 72°F + 460 = 532 R
    - V_2 = End Volume = 3.7cf
    - T_2 = End Temp. = ?°F
  - Select formula, transpose, and solve for T_2

Calculating Charles' Law – 2c

- Answer to example #2:

$$T2 = \frac{T1V2}{V1} = \frac{532\ R \times 3.7\ cf}{4.0\ cf} = \frac{1968\ R}{4.0} = 492\ R =$$

$$492\ R - 460 = 32.1°\ F$$

Gay-Lussac's Law

- Definition: At constant volume, the pressure of a gas varies directly with absolute temperature
- Relevance: Pressure/temperature changes in air-filled spaces (e.g. scuba cylinders, hyperbaric chambers, seafloor habitats)

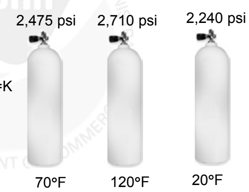
As temperature increases, pressure increases, and vice-versa

Effects of Temperature: Lussac

- As temperature increases, pressure increases
- As temperature decreases, pressure decreases

Rule of Thumb: Steel scuba tank pressure increases about 5 psi per ° F. of temperature change; aluminum about 6 psi.

V=K



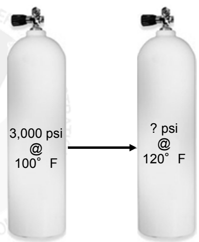
Gay-Lussac's Law Formula

- $\frac{P_1}{P_2} = \frac{T_1}{T_2}$
  - P_1 = Starting pressure (abs)
  - T_1 = Starting temperature (abs)
  - P_2 = Ending pressure (abs)
  - T_2 = Ending pressure (abs)

Always use absolute pressure and temperature when working Gay-Lussac's gas law problems

Calculating Gay-Lussac's Law – 1a

- Example #1:
  - An 80 cf aluminum scuba cylinder is filled to 3000 psig and the temperature inside the tank reaches 100°F.
  - How many PSI will be in the tank if the temperature of the gas increases to 120°F?



Calculating Gay-Lussac's Law – 1b

- Calculating example:
  - Determine factors:
    - P1 = Start pressure = 3,000 psig + 14.7 psi = 3,014.7 psia
    - T1 = 100°F. + 460 = 560 R.
    - P2 = End Pressure = ?psig
    - T2 = End Temp. = 120°F. + 460 = 580 R.
  - Select formula, transpose, solve for P2, and determine amount of increase

Calculating Gay-Lussac's Law – 1c

- Answer to example #1:

$$P2 = \frac{P1T2}{T1} = \frac{3{,}014.7 \text{ psia} \times 580\ \text{R}}{560\ \text{R}} = \frac{1{,}748{,}526 \text{ psia}}{560} =$$

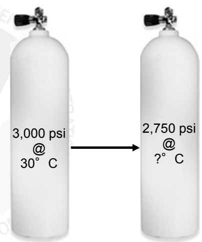
3,122.34 psia - 14.7 psi = 3,107.64 psig

Note: Estimated pressure increase before calculating is: 6 psi x 20° F. = +120 psig increase.

Calculated pressure increase is +107 psig!

Calculating Gay-Lussac's Law – 2a

- Example #2:
  - An 80cf aluminum scuba cylinder at a temperature of 30°C with 3000 psig will decrease to 2750 psig at what temperature °C ?



Calculating Gay-Lussac's Law – 2b

- Calculating example:
  - Determine factors:
    - P_1 = Start pressure = 3,000 psig + 14.7 psi = 3,014.7 psia
    - T_1 = 30°C + 273 = 303 K
    - P_2 = End pressure = 2750 psig + 14.7 psi + 2764.7 psia
    - T_2 = End Temp. = ?°C
  - Select formula, transpose, solve for T2, and determine end temperature

Calculating Gay-Lussac's Law – 2c

- Answer to example #2:

$$T2 = \frac{T1P2}{P1} = \frac{303\text{ K} \times 2764.7\text{ psia}}{3014.7\text{ psia}} = 278\text{ K} =$$

$$\begin{array}{r} 278\text{ K} \\ -273 \\ \hline 5 \\ ^\circ\text{C} \end{array}$$

Henry's Gas Law

- Henry's Law definition
- Relevance of Henry's Law to diving
- Basics of gas absorption and elimination
- Soda pop analogy

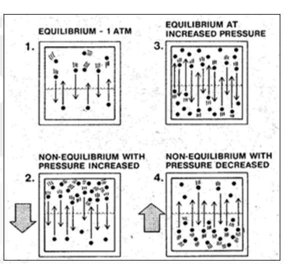
Henry's Gas Law

- Definition: "The amount of any gas that will dissolve in a liquid at a given temperature is a function of the partial pressure of the gas that is in contact with the liquid and the solubility coefficient of the gas in the particular liquid"
- Relevance: Decompression sickness (DCS), decompression tables and dive computer development

At surface our bodies are saturated with ≈ 1 liter of N2. If a diver stays at 60 feet for an extended period of time, their body would be saturated with ≈ 3 liters of N2

Gas Absorption & Elimination-1

- During descent excess gas dissolves into a diver's body
- At the bottom, gas continues to dissolve until the diver's body is "saturated" for a given pressure
- During ascent, gas comes out of solution



The Soda Pop Analogy

- Soda is saturated with gas (CO_2)
- Pressure (sealed bottle) keeps the gas in solution
- Rapidly reducing the pressure causes gas to rush out of solution and form bubbles
- A saturated diver ascending rapidly can experience a similar effect!
- Note: A bottle of soda with a slow leak does not fizz when opened slowly

Always ascend slowly to allow excess gas to escape!

Knowledge check…..

- Boyle's gas law deals with:
  - Pressure and temperature
  - Pressure and volume
  - Volume and temperature
- According to Boyle's gas law, a balloon filled with air at depth inside a hyperbaric chamber will ____ during ascent?
  - Increase in size
  - Decrease in size
  - Remain the same

Knowledge check…..

- Charles' gas law deals with:
  - Pressure and temperature
  - Pressure and volume
  - Volume and temperature
- According to Charles' gas law, a filled balloon will ____ in size with a/an ____ in temperature?
  - Increase; decrease
  - Decrease; increase
  - Increase; increase
  - Decrease; decrease

Knowledge check…..

- Gay-Lussac's gas law deals with:
  - Pressure and temperature
  - Pressure and volume
  - Volume and temperature
- According to Gay-Lussac's gas law, a hyperbaric chamber will ____ in temperature during pressurization to depth?
  - Increase
  - Decrease
  - Remain the same

Knowledge check…..

- Dalton's gas law deals with:
  - Partial pressures
  - Gas absorption and elimination
  - Pressure/temperature relationships
- According to Dalton's gas law, the partial pressure of a gas ____ on descent and ____ on ascent.
  - Increases; decreases
  - Decreases; increases

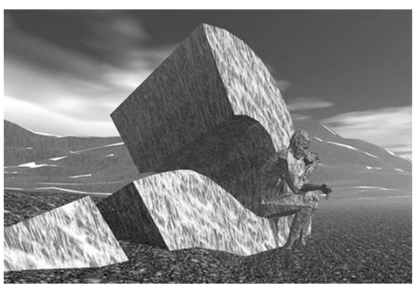
Knowledge check…..

- Henry's gas law deals with:
  - Gas absorption and elimination
  - Tissue half-times
  - Decompression
- According to Henry's gas law, the amount of gas that will be absorbed into the body is based upon:
  - The differential partial pressure of the gas inside and outside the liquid
  - Solubility coefficient of the gas in the liquid
  - The gender of the individual

Key Points

- Boyle's Law deals with pressure and volume relationships
  - assumes no temperature change
  - is an inverse relationship
- There is a direct relationship between pressure and density
- Boyle's Law formula: $P_1V_1 = P_2V_2$
- Always convert pressure units to absolute before working Boyle's Law calculations

Questions?



Atmospheric and Hydrostatic Pressure

Presented by the NOAA Diving Center
Seattle, Washington

Global View

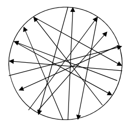
- Definition
- Air pressure
- Water pressure
- Gauge and absolute pressures
- Measuring pressure
- Key Points

Introduction

- **Need & value**: As NOAA divers performing underwater tasks, we need to calculate pressure at depth, gas volume changes caused by changing pressure, the partial pressures of gases, and more.
- **Effect**: When we learn the fundamentals of physics and use them properly, we can solve diving problems easily and correctly. This lesson focuses on the basic principles of calculating for pressure and is a foundation for more complex calculations we will learn in future lessons.

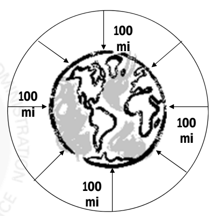
Intro to Pressure

- Pressure is defined as, "Force acting on a unit area."
  - Force per area (l x w)
- Gases exert force, or pressure, because they are composed of billions of molecules which are always in motion
- The more molecules present and the faster they are moving, the greater the pressure
- Each time a molecule strikes another molecule or an object it exerts a force or pressure against it



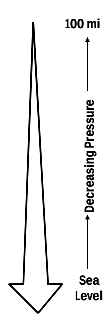
Air Pressure - 1

- Air exists in the atmosphere from sea level up to approximately 100 miles in space
- A person at sea level experiences the full weight, or pressure, of these molecules from the atmosphere
- Consequently, air pressure is commonly referred to as atmospheric pressure



Air Pressure - 2

- At sea level, the pressure exerted by the total number of molecules in a column of air 1 inch by 1 inch is 14.7 pounds per square inch, or 1 atmosphere (ATM)
- As one ascends in altitude, there is less air, or molecules, on top of them equating to less pressure being exerted upon them
- A balloon filled with air at sea level will <u>increase in size</u> at altitude due to the <u>decreased pressure</u> exerted on the outside of the balloon



Air Pressure - 3

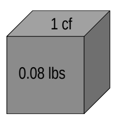
TABLE 4.2
Pressure Variations with Altitude

Altitude, ft	Pressure, mmHg	Pressure, psi	Pressure, atm*
0	760.0	14.70	1.000
1000	732.9	14.17	0.964
2000	706.7	13.67	0.930
3000	681.2	13.17	0.896
4000	656.4	12.70	0.864
5000	632.4	12.23	0.832
6000	609.1	11.78	0.801
7000	586.5	11.35	0.772
8000	584.6	10.92	0.743
9000	543.3	10.51	0.715
10000	522.8	10.11	0.588
11000	502.8	9.73	0.662
12000	483.5	9.35	0.636
13000	464.8	8.99	0.612
14000	446.6	8.64	0.588
15000	429.1	8.31	0.565
16000	412.1	7.97	0.542
17000	395.7	7.66	0.521
18000	379.8	7.35	0.500
19000	364.4	7.04	0.479
20000	349.5	6.76	0.461

* U.S. standard atmosphere.

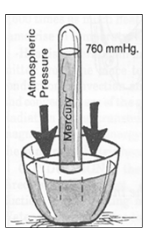
Discovery of Air Pressure - 1

- Galileo (Italian physicist/mathematician/ inventor…)
  - Weighed empty glass container
  - Pumped air into container, then sealed it
  - Re-weighed container
- Torricelli (Italian physicist/mathematician)
  - Determined that fresh water couldn't be pumped out of a well using a suction pump when water had to rise more than 34 feet



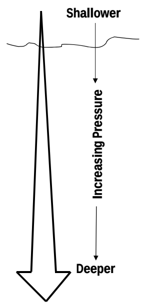
Discovery of Air Pressure - 2

- Torricelli, Con't.
  - Theorized the rise of the water was actually caused by the weight of the atmosphere pushing the water into the vacuum created by the pump
  - Substituting mercury (Hg) for water, Torricelli repeated experiment
  - Concluded the weight of atmospheric pressure on the surface of the bowl kept the mercury in the tube at a height of ~760 mm



Water Pressure

- Definition: The pressure exerted by a fluid on an immersed body.
  - Commonly referred to as Hydrostatic or Gauge pressure.
- Water pressure increases with depth due to the ever increasing weight of the water above
- Changes in water pressure affect our bodies dramatically

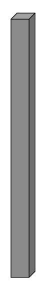


Discovery of Water Pressure

- Pascal (French physicist/ mathematician)
  - Repeated Torricelli's experiment in full-scale using glass tube and water
  - Found the weight of atmospheric pressure would offset the weight of a 1" x 1" column of fresh water 34 feet high
  - Also found the weight of atmospheric pressure would offset the weight of a 1" x 1" column of sea water 33 feet high

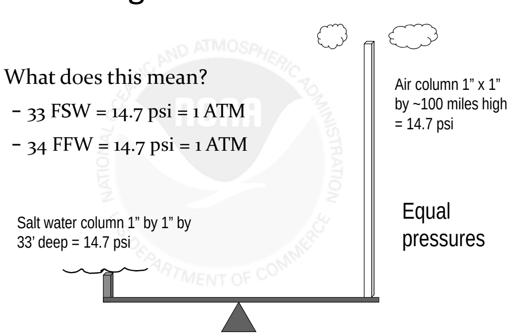
One square inch of salt water 33 feet deep weighs 14.7 lbs.

One square inch of fresh water 34 feet deep weighs 14.7 lbs.



Measuring Water Pressure - 1

- What does this mean?
  - 33 FSW = 14.7 psi = 1 ATM
  - 34 FFW = 14.7 psi = 1 ATM



Measuring Water Pressure - 2

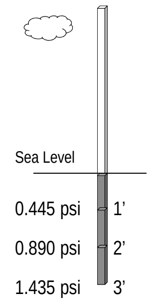
- Equivalent values:
  - 33 FSW = 14.7 psi = 1 ATM
  - 34 FFW = 14.7 psi = 1 ATM

<u>Salt Water</u>: pressure per foot of depth

14.7 psi / 33 feet = 0.445 psi/ft

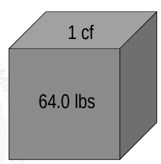
<u>Fresh Water</u>: pressure per foot of depth

14.7 psi / 34 feet = 0.432 psi/ft



Measuring Water Pressure - 3

- Salt water:
  - one cubic foot weighs 64 lbs
- Fresh water:
  - one cubic foot weighs 62.4 lbs
- Air:
  - one cubic foot weighs 0.08 lbs

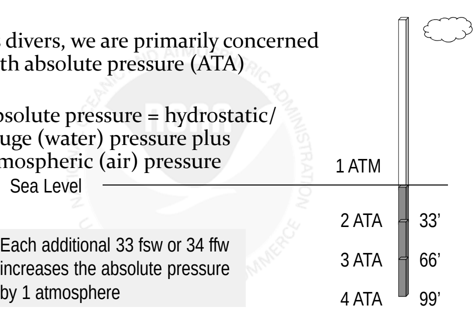


Pressure is force per unit area

64 lbs (weight) / 144 in^2 (area) = 0.445 psi (pressure)

Absolute Pressure

- As divers, we are primarily concerned with absolute pressure (ATA)
- Absolute pressure = hydrostatic/ gauge (water) pressure plus atmospheric (air) pressure



Each additional 33 fsw or 34 ffw increases the absolute pressure by 1 atmosphere

Volumetric Changes By Depth

Salt Water

0' → 33 FSW	= 1 ATM → 2 ATA	= 100% ΔP	= 50% ΔV
33' → 66 FSW	= 2 ATA → 3 ATA	= 50% ΔP	= 33% ΔV
66' → 99 FSW	= 3 ATA → 4 ATA	= 33% ΔP	= 25% ΔV
99' → 132 FSW	= 4 ATA → 5 ATA	= 25% ΔP	= 20% ΔV

Fresh Water

0' → 34 FFW	= 1 ATM → 2 ATA	= 100% ΔP	= 50% ΔV
34' → 68 FFW	= 2 ATA → 3 ATA	= 50% ΔP	= 33% ΔV
68' → 102 FFW	= 3 ATA → 4 ATA	= 33% ΔP	= 25% ΔV
102'→ 136 FFW	= 4 ATA → 5 ATA	= 25% ΔP	= 20% ΔV

Like Units

- Pressure can be measured in several units:
  - FSW, FFW, psi, psia, psig, ATM, ATA, mmHG
- Always use absolute pressure for gas law calculations
- When converting from Gauge to Absolute Pressure you must use Like Units of Measurement

GAUGE	ABSOLUTE
FSW	ADD 33
PSI	ADD 14.7
ATM	ADD 1
mm Hg	ADD 760

Pressure Conversions

Units	PSIG	PSIA	ATM	ATA	FSW	FSWA	FFW	FFWA
PSIG	*	Add 14.7	Divide by 14.7	Add 14.7, divide 14.7	Divide by .445	Divide by .445 + 33	Divide by .432	Divide by .432 + 34
PSIA	Minus 14.7	*	Minus 14.7, divide 14.7	Divide by 14.7	Minus 14.7, divide .445	Divide by .445	Minus 14.7, Divide .432	Divide by .432
ATM	Times 14.7	Times 14.7, add 14.7	*	Add 1	Times 33	Times 33 + 33	Times 34	Times 34 + 34
ATA	Minus 1, times 14.7	Times 14.7	Minus 1	*	Times 33, minus 33	Times 33	Times 34, minus 34	Times 34,
FSW	Times .445	Times .445, add 14.7	Divide by 33	Add 33, divide 33	*	Add 33	Times 1.03	Times 1.03 + 34
FSWA	Minus 33, times .445	Times .445	Minus 33, Divide 33	Divide by 33	Minus 33	*	Minus 33, times 1.03	Times 1.03
FFW	Times .432	Times .432, add 14.7	Divide by 34	Add 34, divide 34	Times .97	+ 34, Times .97	*	Add 34
FFWA	Minus 34, times .432	Times .432	Minus 34, Divide 34	Divide by 34	Minus 34, times .97	Times .97	Minus 34	*

* = Knowns

Calculating Pressure - 1

- Question #1:
  - What is the pressure at 60 fsw expressed in psia?
  - (depth) x (psi/fsw) = psig + 14.7 psi = psia
- Answer:

  1) (60 fsw) x (0.445 psi/fsw) = 26.7 psig

  2) 26.7 psig + 14.7 psi =

  = 41.4 psia

Note: 14.7 psi divided by 33 fsw = 0.445 psi/fsw

Calculating Pressure - 2

- Question #2:
  - What is the pressure at 60 fsw expressed in ATA?
  - $\frac{\text{(Depth + 33 fsw)}}{\text{33 fsw}}$
- Answer:

  = $\frac{\text{(60 fsw+ 33 fsw)}}{\text{33 fsw}}$ =

  = 2.82 ATA

Calculating Pressure - 3

- Question #3:
  - At what depth (fsw) will the pressure be 73.425 psig?
  - psig / (psi/fsw)
- Answer:

  = 73.425 psig / (0.445 psi/fsw)

  = 165 fsw

Note: Unless advised otherwise, calculate depth in gauge pressure, not absolute.

Key Points

- Pressure is weight or force per unit area
- Air weighs 0.08 lbs/ft^3 & exerts 14.7 psi or 760 mm Hg
- Sea water weighs 64 lbs/ft^3 & exerts 0.445 psi/fsw
- Fresh water weighs 62.4 lbs/ft^3 & exerts 0.432 psi/ffw
- Pressure has many units: psi, psia, psig, ATM, feet of depth, ATA, mmHG
- 33 FSW = 14.7 psi = 1 ATM = 760 mmHG = 34 FFW
- Pressure decreases with altitude and increases with depth

Diving Physiology

DIVING REFLEX

- Immersion in cold water may cause:
  - Tachycardia
  - Hypertension
  - Hyperventilation

Pennefather, J. (2002) Cold and Hypothermia. In: Edmonds, Lowry, Pennefather, & Walker. *Diving and Subaquatic Medicine, 4th Ed.* Hodder Arnold. Ch 28.

DIVING REFLEX

- Diving response initiated during apnea and augmented with facial immersion in cold water.

Kjeld T, Pott, FC & Secher NH. Facial immersion in cold water enhances cerebral blood velocity during breath-hold exercise in humans. *Jounal of Applied Physiology* 106: 1243-1248, 2009.

The Diving Response Includes:

- Peripheral vasoconstriction
- Reduced cardiac output
- Bradycardia

↑ Vasoconstriction
↓ CO
↓ HR

Kjeld T, Pott, FC & Secher NH. Facial immersion in cold water enhances cerebral blood velocity during breath-hold exercise in humans. *Jounal of Applied Physiology* 106: 1243-1248, 2009.

Diving Response

Dry Breath Hold:

↓ Muscle Oxygenation

↑ Middle Cerebral Artery Mean Flow Velocity

Kjeld T, Pott, FC & Secher NH. Facial immersion in cold water enhances cerebral blood velocity during breath-hold exercise in humans. *Jounal of Applied Physiology* 106: 1243-1248, 2009.

Immersion

- ↑ intrathoracic blood volume up to 700 mL.
- ↑ RAP by up to 18 mmHg.
- Transient ↑ in SV and CO by up to 100%.

Lowry C: *Cardiac problems and sudden death.* In: Edmonds C, Lowry C, Pennefather J, Walker R, ed. *Diving and Subaquatic Medicine,* London: Arnold; 2002:402.

Immersion

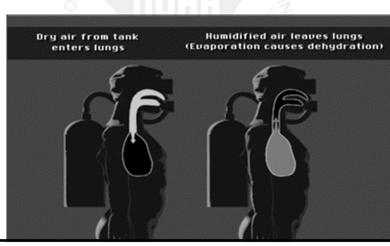
- Urine Production can reach 0.75 ml/min in the first hour of cold water immersion.
- Suppression of ADH
- Reduced renal tubular reabsorption
- Decreased sensitivity of the tubules to ADH.

Dehydration

- Breathing Low Humidity Air
  - Respiration: Loss of fluids from inhalation and exhalation of extremely dry breathing gases

Normal humidity level in the atmosphere is ≈ 30-70%

Humidity level in a pressurized scuba cylinder is ≈ 0.1%



Diving Response

Dry Breath Hold:

↓ Muscle Oxygenation

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Kjeld T, Pott, FC & Secher NH. Facial immersion in cold water enhances cerebral blood velocity during breath-hold exercise in humans. *Jounal of Applied Physiology* 106: 1243-1248, 2009.

CRAMPS

The Diving Response Includes:

- Peripheral vasoconstriction
- Reduced cardiac output
- Bradycardia

↑ Vasocontriction

↓ CO

↓ HR

Kjeld T, Pott, FC & Secher NH. Facial immersion in cold water enhances cerebral blood velocity during breath-hold exercise in humans. *Jounal of Applied Physiology* 106: 1243-1248, 2009.

CRAMPS

↑ Vasoconstriction

↓ Muscle Oxygenation

+ anaerobic metabolism in working muscles?

Kjeld T, Pott, FC & Secher NH. Facial immersion in cold water enhances cerebral blood velocity during breath-hold exercise in humans. *Jounal of Applied Physiology* 106: 1243-1248, 2009.

Ventilation

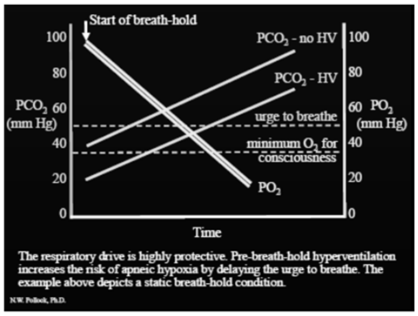
- Ventilatory drive triggered by
  - Increased $PaCO_2$ (hypercapnia) - Primary
  - Decreased PaO_2 (hypoxemia) - Secondary
- Effect
  - Decreases PCO_2 (Hypocapnia)
  - Barely increases PO_2
  - Increases time before PCO_2 demands breathing
  - Unconsciousness from low PO_2 can occur before PCO_2 reaches threshold

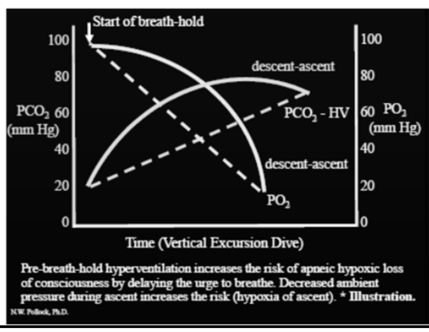
↓ PCO2

Hyperventilation is dangerous

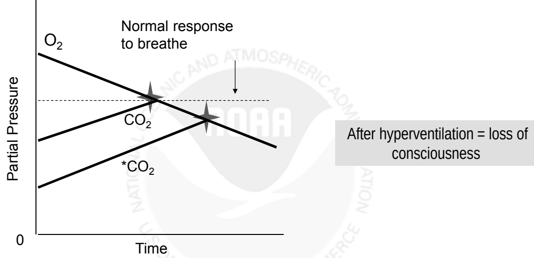
SHALLOW WATER BLACKOUT

- Hypoxia of Ascent (HOA)
- Cause: Excessive hyper-ventilation
- Signs and symptoms:
  - Beginning of breath-hold lightheadedness, faintness, blurred vision
  - At blackout--Unconsciousness, but no symptoms!





Shallow-Water Blackout



- Treatment: Rescue, life-support
- Prevention: Avoid excessive hyperventilation

EFFECTS OF SMOKING

- Short-term effects:
  - CO poisoning
  - Neurologic changes
  - Sensory loss
  - Heart rhythm and rate changes
  - Increased blood pressure
  - Increased DCS risk from blood "clumping"

Effects of Smoking

Smoking increases many of the risks of scuba diving

- Long-term effects:
  - Lung cancer
  - Obstructive lung disease
  - Heart problems
- Prevention:
  - Short term: Abstain at least several hours before diving
  - Long term: Stop smoking

MEMORY & COGNITIVE FUNCTION

MEMORY & COGNITIVE FUNCTION

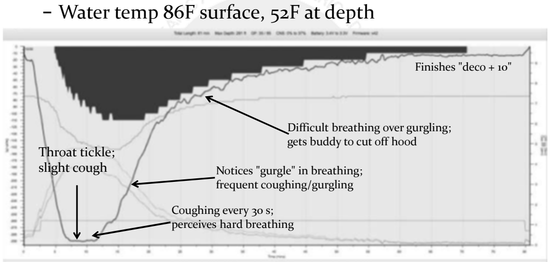
- Neurological effects
  - Some reports of concentration and memory decrements
  - Some have suggested that there is a mild cerebral injury not measurable by neurological exam or psychometric testing

MEMORY & COGNITIVE FUNCTION

- Pathology - Bennett and Elliot, p 680-699
  - Some focal gray matter degeneration
  - Hyalinization of cerebral vessel walls
  - Evidence of neuronal tract degeneration
- Psychological effects

Case Report

- 49 y/o female tech diver
  - Day 4: 291 fsw; total run time 81 min; 10/50
  - Water temp 86F surface, 52F at depth



Case report

- Climbed ladder wearing gear to exit water
  - Good strength and balance
- Chief Complaints
  - Frequent modest cough, dyspnea, gurgling

Differential Diagnosis

- Decompression sickness?
  - Symptoms developed on the bottom
- Saltwater aspiration?
- Underlying cardiac disease?

Case report

- Surface First Aid
  - O_2 by demand mask; cough improved over 15 min
  - Met ambulance at dock after 20 min on boat
- EMS/Evac
  - Symptoms trigger protocol for helo to regional chamber
  - Patient refused; transport by ground to local hospital
- Hospital treatment
  - O_2, albuterol, solu-medrol, lasix

Case report:

Immersion Pulmonary Edema (IPE)

Day 1; 1630

Day 2; 0900

Immersion Pulmonary Edema (IPE)

- Fluid shift from capillaries into interstitial tissue of lungs
- Onset
  - Typically within 30-40 min of exposure
- Symptoms
  - Cough
  - Dyspnea
  - Possibly blood-tinged sputum
  - No chest pain

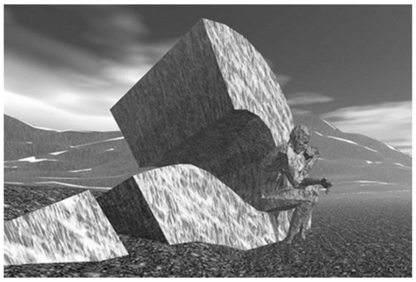
Immersion Pulmonary Edema (IPE)

- Treatment
  - Remove from water, normobaric O2, bed rest
  - Diuretics, inhaled beta-2 agonist
  - Consider CPAP
- Return to diving?
  - Probable following a single incident and after cardiac workup.
  - Doubtful after repeat insult

IPE Contributing Factors

- Central blood volume increase
  - Immersion = blood shift to thorax
  - Hyperhydration
  - Cold stress
- Work of breathing increase
  - Negative pressure breathing – immersion; influenced by body position and equipment (OC, CCR, snorkel)
  - Gas density
  - Exertion
- Pulmonary artery pressure elevation
  - Capillary stress failure and increased permeability

Questions?



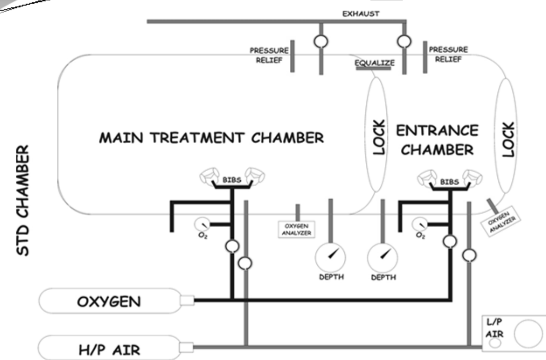
Introduction to PVHO

History

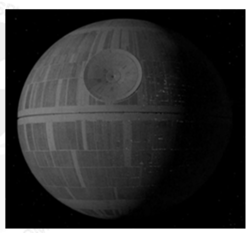
- ASME Safety Committee formed in 1974, with first publication of PVHO-1 in 1977
- Developed specific guidelines to meet areas not specifically addressed in Section VIII, Division 1 of the Boiler and Pressure Vessel Code
  - **Use of Pressure Relief Devices*
  - **Requirement for Viewports*
- Subsequent PVHO-1 revisions have addressed
  - **Design and Use of Acrylic Viewports*
  - **Integral Piping System Design Requirement*

Pressure Vessels for Human Occupancy

- *ASME defines PVHO as a pressure vessel that encloses a human being within its pressure boundary while it is under internal or external pressure that exceeds a 2 psi differential pressure. PVHOs include, but are not limited to, submersibles, diving bells, personnel transfer capsules, decompression chambers, recompression chambers, hyperbaric chambers, high altitude chambers, and medical hyperbaric oxygenation facilities.*


EXHAUST
PRESSURE RELIEF
EQUALIZE
PRESSURE RELIEF
MAIN TREATMENT CHAMBER
LOCK
ENTRANCE CHAMBER
LOCK
STD CHAMBER
BIBS
BIBS
OXYGEN ANALYZER
OXYGEN ANALYZER
DEPTH
DEPTH
OXYGEN
H/P AIR
L/P AIR

4



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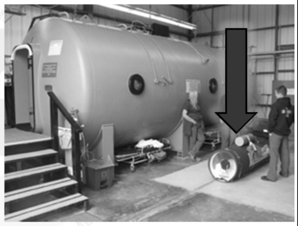

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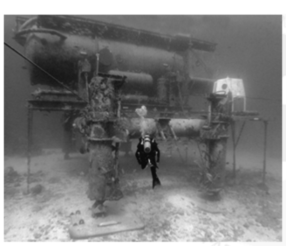

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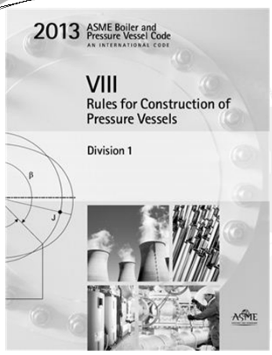

- Section VIII provides requirements applicable to the design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psig.
- Such pressure vessels may be fired or unfired. Specific requirements apply to several classes of material used in pressure vessel construction, and also to fabrication methods such as welding, forging and brazing.
- It contains mandatory and nonmandatory appendices detailing supplementary design criteria, nondestructive examination and inspection acceptance standards. Rules pertaining to the use of the U, UM and UV Code symbol stamps are also included.

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Publications

- Section 1: General
- Section 2: Viewports
- Section 3: QA for Manufacturers
- Section 4: Piping Systems
- Section 5: Medical Hyperbaric
- Section 6: Diving Systems
- Section 7: Submersibles

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Section 1

References Boiler Code for specific design and fabrication criteria to include:

1. Cylinder Geometry
2. Allowable Material
3. Stiffening Requirement
4. Hatch/Door Design
5. Pressure Testing
6. Use of Non-Metallic Material

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Section 1 General

Fig. 1-9(b)-1 Form of Nameplate, U.S. Customary

PVHO-1

Certified by

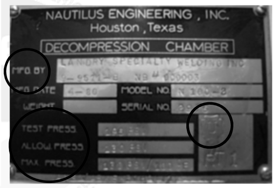
(Name of manufacturer)

_____ psi internal _____ psi external
(Maximum allowable working pressures)

_____°F maximum _____°F minimum
(Design temperature range)

(Manufacturer's serial number) (Year built)

(Design criteria)



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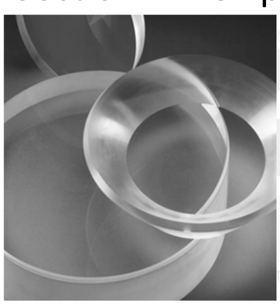
Section 2 Viewports



- Window Design
  1. *Shape*
  2. *Seating*
- Material of Construction
  1. *Acrylic Sheet Casting*
- Fabrication
  1. *Machining*
  2. *Annealing*
- Inspection
- Testing
- Installation

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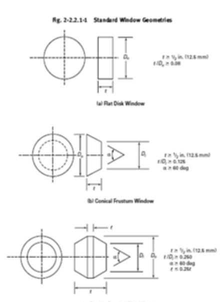
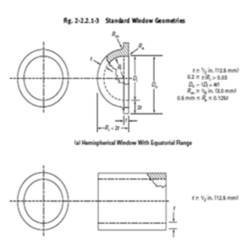
Standard Acrylic Geometry





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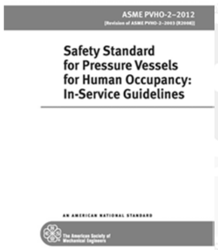
PVHO-2


ASME PVHO-2–2012
[Revision of ASME PVHO-2–2003 (R2008)]

Safety Standard for Pressure Vessels for Human Occupancy: In-Service Guidelines

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

- In-use extension of PVHO-1, Section 2
- Handling and care instruction
- Appropriate inspection and maintenance interval
- Tables to assist in quantifying inspection findings
- Detailed instruction and forms resource for the repair process

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Section 4 Piping Systems

- Discusses detailed internal and external piping system design to include:

1. Materials
2. Service requirement
3. Valves
4. Breathing Gas System
5. Depth Gauges
6. Marking

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Table C-1 U.S. Navy

Name	Designation	Color
Oxygen	O_2	Green
Nitrogen	N	Light gray
Air (low pressure)	ALP	Black
Air (high pressure)	AHP	Black
Helium	He	Buff
Helium–oxygen mix	He–O_2	Buff and green

GENERAL NOTE: Taken from *U.S. Navy Diving Manual NAVSHIPS 0994-001-9010.*

Table C-2 IMO

Name	Symbol	Color
Oxygen	O_2	White
Nitrogen	N_2	Black
Air	Air	White and black
Carbon dioxide	CO_2	Gray
Helium	He	Brown
Oxygen–helium mix	O_2–He	White and brown

GENERAL NOTE: Taken from *IMO Resolution A536*, "Code of Safety for Diving Systems."

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Table 21-1. *Recompression Chamber Line Guide.*

Function	Designation	Color Code
Helium	HE	Buff
Oxygen	OX	Green
Helium-Oxygen Mix	HE-OX	Buff & Green
Nitrogen	N	Light Gray
Nitrogen Oxygen Mix	N-OX	Light Gray & Green
Exhaust	E	Silver
Air (Low Pressure)	ALP	Black
Air (High Pressure)	AHP	Black
Chilled Water	CW	Blue & White
Hot Water	HW	Red & White
Potable Water	PW	Blue
Fire Fighting Material	FP	Red

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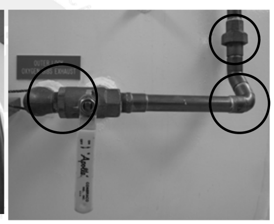
Section 4

Exterior Tube

Exterior Brazed



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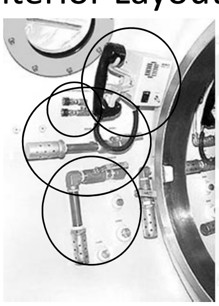
Interior Layout



- Inlet
- Exhaust
- BIBS
- Electrical

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Valve Types

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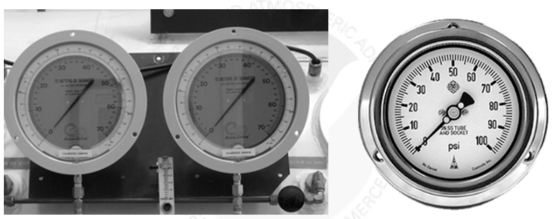
Gauges



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Fire Suppression

Treatment Lock required to have means of extinguishing fire. This can include:

1. Automated fire suppression system
2. Fire hose/ hand line
3. Fire Extinguisher
4. Bucket of water with fire blanket

Most clinical chamber systems will include both automated systems and hand lines.

Most deck decompression chamber systems will include only fire extinguishers and fire blankets

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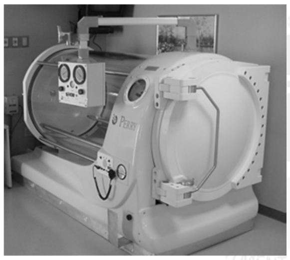
Section 5 Medical HBO



- Necessitates compliance with existing PVHO-1 *as well as* conformity to NFPA 99 guidelines
- Waves requirement for transfer lock in chambers rated to 3 ATA or less

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Section 6 Diving Systems

Consideration given to the type of service and operational environment each is exposed to in support of commercial diving operations

- Fabrication considerations for differential temperatures and corrosive marine environments
- Dynamic loading from transport, lifting, vibration, and wave action
- Distinct ergonomic space considerations for saturation systems
- Requirement for sanitation facilities (showers, toilets) in saturation
- Provision for design and integration of mating clamp and closures
- Design parameters for bell and PTC with respect to impact, mating, and ballast

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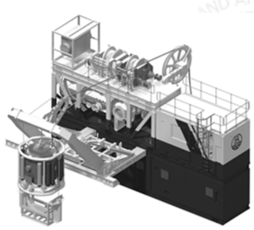
Section 6 Diving Systems



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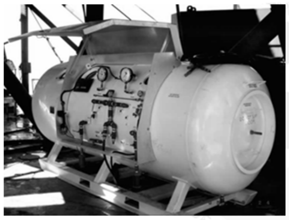
Section 6 Diving Systems



Treatment Air Supply

Table 21-2. Recompression Chamber Air Supply Requirements.

Recompression Chamber Configuration	Primary Air Requirement	Secondary Air Requirement
CATEGORY A: No BIBS overboard dump No CO_2 scrubber No air BIBS No O_2 and CO_2 monitor	Sufficient air to press the IL once and the OL twice to 165 fsw and vent during one TT6A for one tender and two patients with maximum extensions.	Sufficient air to press the IL and OL once to 165 fsw and vent for one hour at 70.4 scfm.
CATEGORY B: BIBS overboard dump No CO_2 scrubber No air BIBS O_2 and CO_2 monitors	Sufficient air to press the IL once and the OL twice to 165 fsw and vent for CO_2 during one TT6A for one tender and two patients with maximum extensions.	Sufficient air to press the IL and OL once to 165 fsw and vent for one hour at 70.4 scfm.
CATEGORY C: BIBS overboard dump CO_2 scrubber No air BIBS O_2 and CO_2 monitors	Sufficient air to press the IL once and the OL twice to 165 fsw.	Sufficient air to press the IL and OL once to 165 fsw and vent for one hour at 70.4 scfm.
CATEGORY D: BIBS overboard dump CO_2 scrubber Air BIBS O_2 and CO_2 monitor	Sufficient air to press the IL once and the OL twice to 165 fsw. (For TRCS, sufficient air to power CO_2 scrubbers must be included)	Sufficient air to press the IL and OL once to 165 fsw and enough air for one tender and two patients (when not on O_2) to breathe air BIBS during one TT6A with maximum extensions.
CATEGORY E: BIBS overboard dump CO_2 scrubber O_2 and CO_2 monitor Spare CO_2 scrubber Secondary power supply NITROX BIBS No Air BIBS	Sufficient air to press the IL once and the OL twice to 165 fsw.	Sufficient air to press the IL and OL once to 165 fsw and enough air/NITROX for one tender and two patients (when not on O_2) to breathe air/NITROX BIBS during one TT6A with maximum extensions.

Notes:
1) Additional air source per PSOB will be required for TT4, 7 or 8.
2) For chambers used to conduct Sur "D" sufficient air is required to conduct a TT6A in addition to any planned Sur "D."
3) The requirement for BIBS overboard dump can also be satisfied with closed circuit BIBS with CO_2 scrubbers.

How do we know?

21-4 GAS SUPPLY

A recompression chamber system must have a primary and a secondary air supply system that satisfies Table 21-2. The purpose of this requirement is to ensure the recompression chamber system, at a minimum, is capable of conducting a Treatment Table 6A (TT6A).

21-4.1 Capacity. Either system may consist of air banks and/or a suitable compressor. The primary air supply system must have sufficient air to pressurize the inner lock once to 165 fsw and the outer lock twice to 165 fsw and ventilate the chamber as specified in Table 21-2.

- Primary System Capacity:

$C_p = (5 \times V_{il}) + (10 \times V_{ol}) + RV$

Where:

C_p = minimum capacity of primary system in SCF
V_{il} = volume of inner lock
V_{ol} = volume of outer lock
5 = atmospheres equivalent to 165 fsw
10 = twice the atmospheres equivalent to 165 fsw
RV = required ventilation. See paragraph 21-5.4 for Category A and B ventilation requirements. Not used for Category C, D, and E.

The secondary air supply system must have sufficient air to pressurize the inner and outer locks once to 165 fsw plus ventilate the chamber as specified in Table 21-2.

- Secondary System Requirement:

$C_s = (5 \times V_{il}) + (5 \times V_{ol}) + RV$

Where:

C_s = minimum capacity of secondary system in SCF
V_{il} = volume of inner lock
V_{ol} = volume of outer lock
5 = atmospheres equivalent to 165 fsw
RV = required ventilation. For Category A, B, and C, use 4,224 for ventilation rate of 70.4 scfm for one hour. For Category D and E, calculate air or NITROX required for two patients and one tender to breathe BIBS (when not on O_2) during one TT6A with maximum extensions.

Pre-dive Checklists

RECOMPRESSION CHAMBER PREDIVE CHECKLIST	
Equipment	**Initials**
Chamber	
System certified	
Cleared of all extraneous equipment	
Clear of noxious odors	
Doors and seals undamaged, seals lubricated	
Pressure gauges calibrated/compared	
Air Supply System	
Primary and secondary air supply adequate	
One-valve supply: Valve closed	
Two-valve supply: Outside valve open, inside valve closed, if applicable	
Equalization valve closed, if applicable	
Supply regulator set at 250 psig or other appropriate pressure	
Fittings tight, filters clean, compressors fueled	
Exhaust System	
One-valve exhaust: Valve closed and calibrated for ventilation	
Two-valve exhaust: Outside valve open, inside valve closed, if applicable	
Oxygen Supply System	
Cylinders full, marked as BREATHING OXYGEN, cylinder valves open	
Replacement cylinders on hand	
Built in breathing system (BIBS) masks installed and tested	
Supply regulator set in accordance with OPs	
Fittings tight, gauges calibrated	
Oxygen manifold valves closed	
BIBS dump functioning	

RECOMPRESSION CHAMBER PREDIVE CHECKLIST		
Equipment		**Initials**
Electrical System		
Lights		
Carbon dioxide analyzer calibrated		
Oxygen analyzer calibrated		
Temperature indicator calibrated		
Carbon dioxide scrubber operational		
Chamber conditioning unit operational		
Direct Current (DC) power supply		
Ground Fault Interrupter (GFI)		
Communication System		
Primary system tested		
Secondary system tested		
Fire Prevention System		
Tank pressurized for chambers with installed fire suppression systems		
Combustible material in metal enclosure		
Fire-retardant clothing worn by all chamber occupants		
Fire-resistant mattresses and blankets in chamber		
Means of extinguishing a fire		
Miscellaneous		
Inside Chamber:	CO_2-absorbent canister with fresh absorbent installed	
	Urinal	
	Primary medical kit	
	Ear protection sound attenuators/ear protectors (1 set per person) Must have a 1/16" hole drilled to allow for equalization.	
Outside Chamber:	Heater/chiller unit	
	Stopwatches for recompression treatment time, decompression time, personnel leaving chamber time, and cumulative time	
	Fresh CO_2 scrubber canister	
	U.S. Navy Diving Manual, Volume 5	
	Ventilation bill	
	Chamber log	
	Operating Procedures (OPs) and Emergency Procedures (EPs)	
	Secondary medical kit	
	Bedpan (to be locked in as required)	

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Post-dive Checklist

RECOMPRESSION CHAMBER POSTDIVE CHECKLIST	
Equipment	**Initials**
Air Supply	
All valves closed	
Air banks recharged, gauged, and pressure recorded	
Compressors fueled and maintained per technical manual/PMS requirements	
View Ports and Doors	
View ports checked for damage; replaced as necessary	
Door seals checked, replaced as necessary	
Door seals lightly lubricated with approved lubricant	
Door dogs and dogging mechanism checked for proper operation and shaft seals for tightness	
Chamber	
Inside wiped clean with Nonionic Detergent (NID) and warm fresh water	
All unnecessary support items removed from chamber	
Blankets cleaned and replaced	
All flammable material in chamber encased in fire-resistant containers	
Primary medical kit restocked as required	
Chamber aired out	
Outer door closed	
CO_2 canister packed	
Deckplates lifted, area below deckplates cleaned, deckplates reinstalled	
Support Items	
Stopwatches checked and reset	
U.S. Navy Diving Manual, Operating Procedures (OPs), Emergency Procedures (EPs), ventilation bill and pencil available at control desk	
Secondary medical kit restocked as required and stowed	
Clothing cleaned and stowed	
All entries made in chamber log book	
Chamber log book stowed	

RECOMPRESSION CHAMBER POSTDIVE CHECKLIST	
Equipment	**Initials**
Oxygen Supply	
BIBS mask removed, cleaned per current PMS procedures, reinstalled	
All valves closed	
System bled	
Breathing oxygen cylinders fully pressurized	
Spare cylinders available	
System free of contamination	
Exhaust System	
One-valve exhaust: valves closed	
Two-valve exhaust: inside valves closed	
Two-valve exhaust: outside valves opened	
Electrical	
All circuits checked	
Light bulbs replaced as necessary	
Pressure-proof housing of lights checked	
All power OFF	
Wiring checked for fraying	

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Section 7 Submersibles

- Design considerations must include operational maximums (depth, current, speed,)
- Considerations are made for internal power distribution (lighting, propulsion, life support, environmental control)
- Navigation, propulsion
- Communications
- Depth monitoring
- Buoyancy/CG consideration

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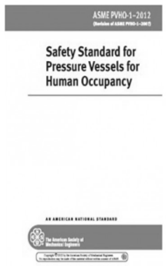
Chamber Staffing



- *NO specific recommendations for staffing levels*
- Number of occupants rating
- Minimum flow ratings based on operational needs for atmospheric and treatment gases

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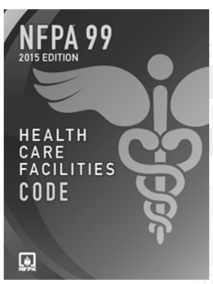

- ONLY *specific* requirement: Hyperbaric Safety Director
- Safety Director, Facility management, and Medical Director responsible for developing, adopting, and enforcing operational procedures
- Medical and Safety Director develop minimum staff qualifications based on:

1. *Number and type of chambers*
2. *Maximum treatment capacity*
3. *Type of HBO therapy provided*

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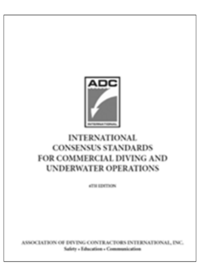

- SSD with planned deco:

1. *Supervisor*
2. *Diver*
3. *Standby*
4. *Two Tenders*

- SSD HeO2

1. *Same as above plus Open Bell*

- Saturation

1. 2 Bell/Sat Supervisors
2. 2 Sat Divers
3. 2 Surface STB divers (sat qual)
4. 2 Life Support Technicians (LST)
5. 2 Sat Technicians
6. 4 Tender/Divers
7. Above plus all necessary PVHO

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SS521-AG-PRO-010
0910-LP-106-0957

REVISION 6

U.S. Navy Diving Manual

Volume 1: Diving Principles and Policies
Volume 2: Air Diving Operations
Volume 3: Mixed Gas Surface Supplied Diving Operations
Volume 4: Closed-Circuit and Semiclosed Circuit Diving Operations
Volume 5: Diving Medicine and Recompression Chamber Operations

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SUPERSEDES SS521-AG-PRO-010, REVISION 5, Dated 15 August 2005.

PUBLISHED BY DIRECTION OF COMMANDER, NAVAL SEA SYSTEMS COMMAND
15 APRIL 2008

MINIMUM MANNING LEVELS FOR AIR DIVING

	Open circuit SCUBA Operations		Surface-Supplied Operations
	Single Diver	Buddy Pair	
Diving Supervisor	1	1	1
Comms and Logs	(a)	(a)	(a)
Console Operator			(a)
Diver	1	2	1
Standby Diver	1	1	1
Diver Tender (b, c)	1(b)		1(b)
Standby Diver Tender	(c)	(c)	1
Total	4(d)	4	5(e)

WARNING
These are the minimum personnel levels required. ORM may require these personnel levels be increased so the diving operations can be conducted safely. See Paragraph 6-1.1 and 6-9.1

NOTES:

(a) Diving Supervisor may perform/assign Comms/Logs or Console Operator positions as necessary or required by the system/operations/mission.

(b) See paragraph 6-8.8.5.2 for Tender Qualifications.

(c) If the standby diver is deployed, the Diving Supervisor shall tend the standby diver.

(d) The diver will be tended or have a witness float attached, see paragraph 7-3.1.7. A tender is required when the diver does not have free access to the surface, see paragraph 7-8.2 for further guidance. During mission essential open circuit SCUBA operations, minimum-manning level may be reduced to three qualified divers at the Diving Supervisor's discretion.

(e) Although five is the minimum number of personnel for the MK III and Extreme Lightweight Dive System (XLDS) operations, six or more is highly recommended based on mission requirements and ORM.

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Figure 13-5. FADS III Mixed Gas System (FMGS).

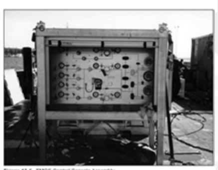
Figure 13-6. FMGS Control Console Assembly.

Designation	Deep-Sea (MK 21, EXO BR MS, KM-37) One Diver	Deep-Sea (MK 21, EXO BR MS, KM-37) Two Divers
Diving Officer	1 (Note 1)	1 (Note 1)
Diving Medical Officer	1 (Notes 1 and 4)	1 (Notes 1 and 4)
Diving Supervisor/Master Diver	1 (Notes 1 and 5)	1 (Notes 1 and 5)
Diving Medical Technician	1 (Notes 1 and 6)	1 (Notes 1 and 6)
Diver	1 (Note 2)	2 (Note 2)
Standby Diver	1 (Note 2)	1 (Note 2)
Tender	3 (Note 2)	5 (Note 2)
Timekeeper/Recorder	1 (Note 2)	1 (Note 2)
Rack Operator	1 (Note 2)	1 (Note 2)
Winch Operator	1 (Note 3)	1 (Note 3)
Console Operator	1 (Note 2)	1 (Note 2)
Total Personnel Required	12	15

Notes:

1. To ensure sufficient properly trained and qualified individuals are assigned to the most critical positions on a surface supplied mixed gas dive station, the following minimum stations shall be manned by formally trained (NDSTC) mixed gas divers:
   Diving Officer
   Master Diver
   Diving Supervisor
2. The following stations shall be manned by formally trained (NDSTC) surface supplied divers:
   Diver
   Standby Diver
   Rack Operator
   Console Operator
   Timekeeper/Recorder
3. The following stations should be a qualified diver. When circumstances require the use of a non-diver, the Diving Officer, Master Diver, and Diving Supervisor must ensure that the required personnel has been thoroughly instructed in the required duties. These stations include:
   Tender
   Standby Tender
   Winch Operator
4. A Diving Medical Officer is required on dive station for all exceptional exposure dives and dives exceeding the equipment normal working limits.
5. Master Diver may serve as the Diving Officer if so designated in writing by the Commanding Officer.
6. A Diving Medical Technician is required on-site when a DMO is not available.

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NOAA DIVING PROGRAM

OPERATING STANDARDS
FOR
NOAA HYPERBARIC CHAMBERS

NOAA Diving Center
7600 Sand Point Way, N.E.
Seattle, WA 98115-0070

- **Multi-lock**
  1. Supervisor/Operator
  2. Inside Tender
  3. Systems operator
  4. Diving Medical Officer
- **Mono-lock/Multi-place**
  1. Supervisor/Operator
  2. Inside Tender
  3. Systems operator
  4. Diving Medical Officer
- **Mono-lock/Monoplace**
  1. Supervisor/Operator
  2. Timekeeper/system operator

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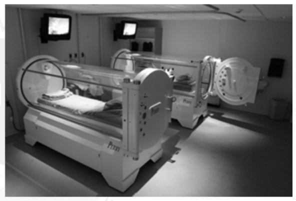

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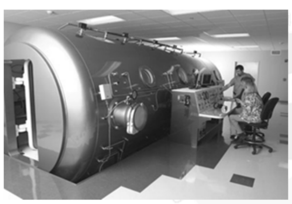


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Training and Certification

DIVER MEDIC
NATIONAL BOARD DIVING HYPERBARIC MEDICAL TECHNOLOGY

UNDERSEA & HYPERBARIC MEDICAL SOCIETY

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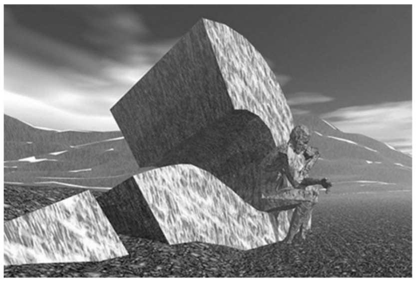
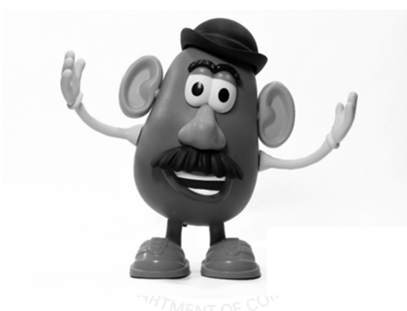
Questions?





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Nitrogen Narcosis

WHAT IS IT?

- A reversible alteration in consciousness that occurs while at depth (usually noticeable around 30 meters or 100 ft)
- Caused by the anesthetic effect of certain gases at high pressure

NITROGEN NARCOSIS

Depths Beyond 100 Feet!

- Individual Variability
- Day-to-Day Variability

Signs and Symptoms of N_2 Narcosis

- Impaired performance mental/manual work
- Dizziness, euphoria, intoxication
- Overconfidence
- Uncontrolled laughter
- Overly talkative
- Memory loss/post-dive amnesia
- Perceptual narrowing
- Impaired sensory function
- Loss of consciousness > 300 ft

Deep Scuba Dives Breathing Air

YEAR	DIVER	DEPTH
1943 1948	Dumas Dumas	203 feet 307 feet
1967 1968	Watts Watson	390 feet 437 feet
1989	Gilliam	452 feet

Dr. Dan Manion surfaces after his 491 foot dive in 1994 to beat Gilliam's record.

Prevention of Nitrogen Narcosis

- Restrict diving depth to less than 100 fsw
- If affected, return immediately to surface
- Plan dive beforehand
  - Max time to be on bottom
  - Any decompression required
  - Minimum air required for ascent
  - Emergency action in event of accident
- Breathe helium/oxygen mixture

How to Beat Narcosis (Francis 2006)

- Be sober, no hangover and drug free
- Be rested and confident
- Use a high quality regulator
- Avoid task loading
- Be over trained
- Approach limits gradually
- Use a slate to plan dive
- Schedule gauge checks and buddy checks
- Be positive, well motivated and prudent

Oxygen Toxicity

Oxygen

8
O
15.999

- Characteristics:
  - Colorless
  - Odorless
  - Tasteless
- Disadvantage:
  - Toxic when excessive amounts are breathed under pressure

Oxygen is the only gas metabolized by the human body

Too much or too little oxygen is dangerous!

Oxygen Toxicity

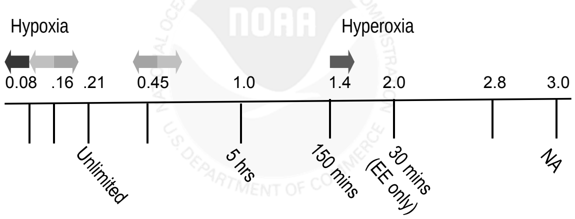
- Oxygen toxicity is generally not a problem for routine air diving operations
  - A diver must dive deeper than 186 fsw before exceeding the 1.4 PO_2 limit
- However, a diver breathing a Nitrox mixture will reach the 1.4 PO_2 limit much shallower than a diver breathing air!

1.4 PO_2			
AIR	NN32	NN36	100% O_2
186 fsw	113 fsw	95 fsw	13 fsw

NOAA PO_2 & Exposure Limits

ATA	CNS SINGLE EXPOSURE (MINS)	PULMONARY 24 HOUR EXPOSURE (MINS)
1.6	45	150
1.5	120	180
1.4	150	180
1.3	180	210
1.2	210	240
1.1	240	270
1.0	300	300
0.9	360	360
0.8	450	450
0.7	570	570
0.6	720	720

Oxygen Limits Continuum



Hyperoxia

- Contributing Factors:
  - Primary
    - FiO_2
    - Depth
    - Duration
    - Physical exertion
  - Secondary
    - CO_2 retention
    - Cold stress
    - Heat stress
    - Individual physiology
- CNS Toxicity:
  - V-vision
  - E-ears
  - N-nausea
  - T-twitching
  - I-irritability
  - D-dizziness
  - C-convulsions

CNS toxicity varies from person to person and from moment to moment

Unit Pulmonary Toxic Dose (UPTD)

1 UPTD = Pulmonary toxicity due to breathing 100% O_2 at a pressure of 1 atm for 1 min

Unit Pulmonary Toxic Dose (UPTD)

1 UPTD = 100% O_2 for 1 min at 1 ATA
USN 5 UPTD 336
USN 6 UPTD 646
USN 6A UPTD 693

UPTD 615 - vital capacity - 2%
UPTD 1425 - vital capacity - 10%

Lung Pathology Phase I

Exudative Phase

- Interstitial and alveolar edema
- Intra-alveolar hemorrhage
- Fibrinous exudate
- Hyaline membranes
- Capillary endothelial cell
- Swelling/destruction
- Type I alveolar epithelial cells destruction

Lung Pathology Phase 2

Subcutaneous Proliferative Phase

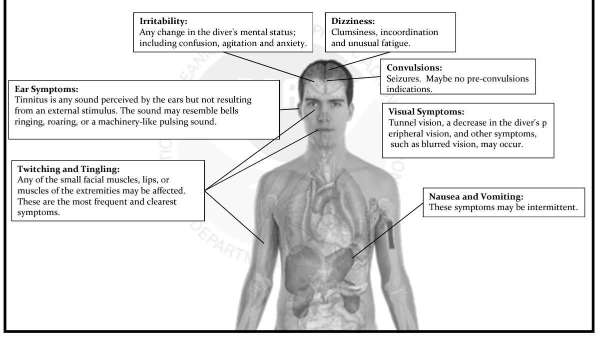
- Interstitial fibrosis
- Fibroblastic proliferation
- Hyperplasia Type II alveolar epithelial cells

Signs and Symptoms of Oxygen Toxicity

V.E.N.T.I.D.C.

- **V**isual Symptoms
- **E**ar Symptoms
- **N**ausea and Vomiting
- **T**witching and Tingling
- **I**rritability
- **D**izziness
- **C**onvulsions

Signs and Symptoms of Oxygen Toxicity



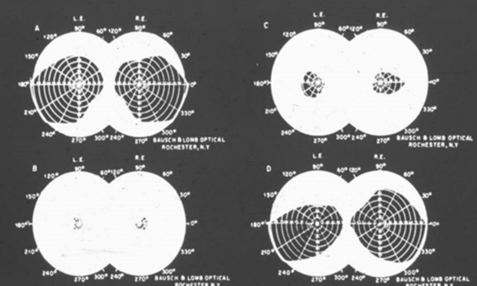
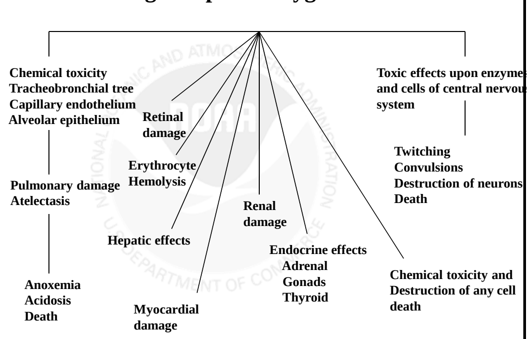


FIG. 9.14. Perimetric measurements of visual fields in the same subject before and after 3.5 h of oxygen breathing at 3 ATA. Normal pre-exposure visual fields shown in A. Visual fields shown in B, C and D, respectively, were obtained 5, 25 and 50 min post-exposure. (From Behnke *et al.* 1935)

Nitric Oxide and Oxygen Convulsions

- Increase in NO overrides O_2 vasoconstriction
- Brain tissue pO_2 increases markedly
- Convulsion follows

EFFECTS OF OXYGEN TOXICITY



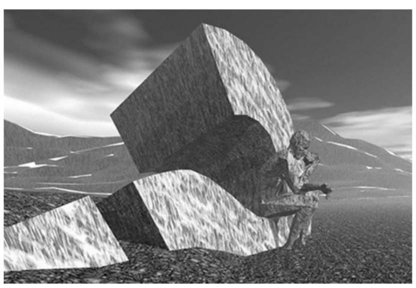
Factors Which Protect Against Oxygen Toxicity

- Intermittent exposure
- Pre-exposure to CO_2
- Tris buffer (tris [Hydroxymethyl] Aminomethane)
- Barbiturates
- Hyperventilation
- Adrenalectomy
- Factors decreasing the metabolic rate

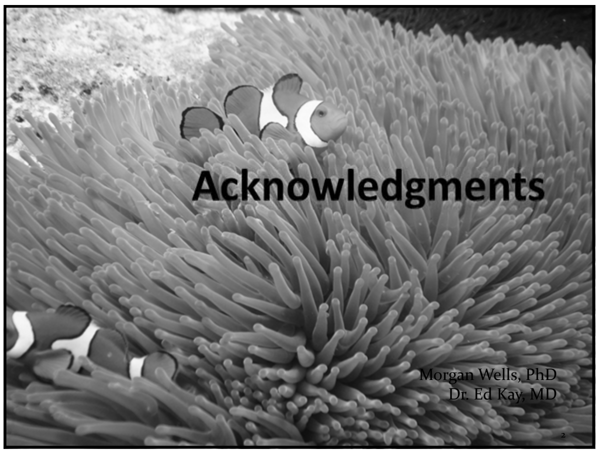
Factors Which Increase Oxygen Toxicity

- XS CO_2 in mixture breathed
- Increased temperature
- Work or exercise
- Respiratory impairment
- Factors increasing the metabolic rate
- Adrenalin

Questions?



NON-PULMONARY BAROTRAUMA



Fitness to Dive

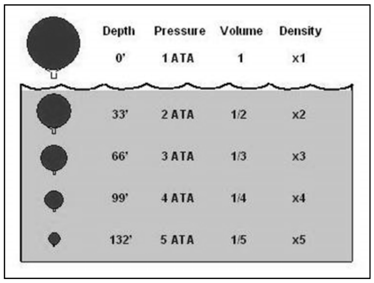
- **Able to do the "work":** breathe, swim, SAVE YOU!
- **Not susceptible to barotrauma:** ear, lung, GI
- **Not susceptible to loss of consciousness (drowning):** convulsions, insulin dependent diabetes, heart block
- **Not pregnant**
- **No diseases that diving could make worse:** sinus or middle ear disease, previous labyrinthine window rupture, heart failure
- **Not 'overly' susceptible to DCI**

Age?	Female gender?
Obesity?	Menses?
Previous decompression illness?	Fatigue, dehydration?
Orthopedic injuries or surgery?	Atrial septal defects, PFO?

Adapted from Moon, RE

Boyles Law

Pressure and Volume - Inversely Proportional



Depth	Pressure	Volume	Density
0'	1 ATA	1	x1
33'	2 ATA	1/2	x2
66'	3 ATA	1/3	x3
99'	4 ATA	1/4	x4
132'	5 ATA	1/5	x5

Squeeze

- MIDDLE EAR SQUEEZE
- EXTERNAL EAR SQUEEZE
- SINUS SQUEEZE
- TOOTH SQUEEZE (BARODONTALGIA)
- BODY (SUIT) / FACE (MASK) SQUEEZE
- STOMACH / INTESTINE
- INNER EAR BAROTRAUMAS

Differential - Ear Pain

- Barotrauma
- Otitis
- Dental Abscess
- TMJ Syndrome
- Lymphadenopathy
- Foreign Body or Cerumen Impaction
- Mastoiditis / Sinusitis / Cellulitis

Class of Drugs	Drug Effects Adverse to Diving
Anticoagulants	Hemorrhage from Barotrauma or Spinal DCS
Narcotics, Marijuana & Alcohol	Impaired judgment & problem solving. Aggravation of nitrogen narcosis
Tranquillizers	Impaired judgment & problem solving. Aggravation of nitrogen narcosis
Anti-depressants	Risk of seizures with Bupropion (Wellbutrin)
Decongestants & Antihistamines	Sleepiness & nasal rebound congestion. Risk of ear barotrauma and O_2 Toxicity with pseudoephedrine (Sudafed)
Motion sickness drugs	Sedation, impaired judgment and aggravation of nitrogen narcosis.
Beta blockers	Reduced ability to respond to needs of stress. Aggravate Raynaud's Phenomenon and asthma
Anti - malarials	Mefloquine (Lariam) psychological & neurological side effects are similar to symptoms of DCS. Doxycycline causes disabling photosensitivity.
Sympathomimetics	Amphetamines, methylphenidate and to a lesser extent pseudoephedrine (CNS stimulants) increase risk of CNS oxygen toxicity. Amphetamines can distort or amplify self-confidence (grandiosity) or increase risk of panic during frightening narcosis

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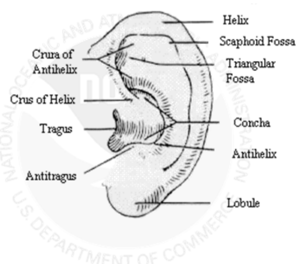
Anatomy of External Ear



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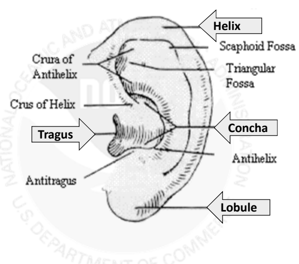
Anatomy of External Ear



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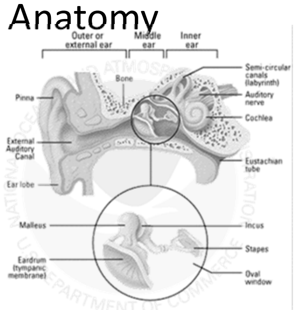
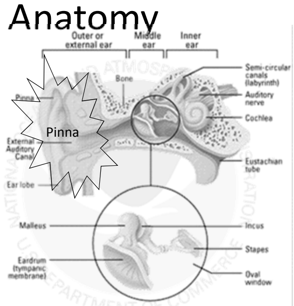
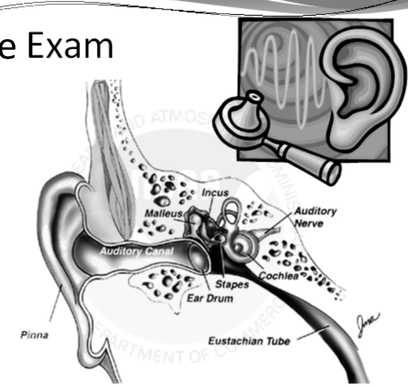
Internal Anatomy



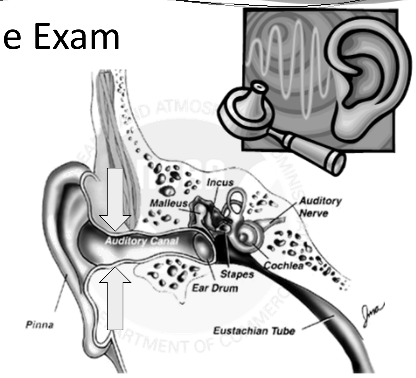
Internal Anatomy



The Exam



The Exam



Ear Wax is Your Friend!

- Waxy sebaceous secretions + skin cells
- Anti-pseudomonal due to acidic PH
- Moisture repelling waxy consistency
- Occasionally needs removal if:
  - Impairs hearing
  - Interferes with hearing aids
  - Impairs inspection
  - Cerumen “dam” causes water trapping

Low Tech Wax Removal

Lighted Ear Curette

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BIONIX

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Doc's Preferred View

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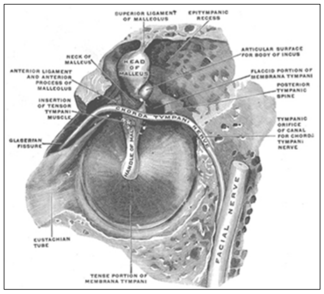
TM -Back side



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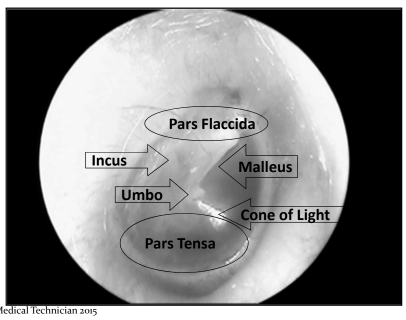
Doc's Preferred View



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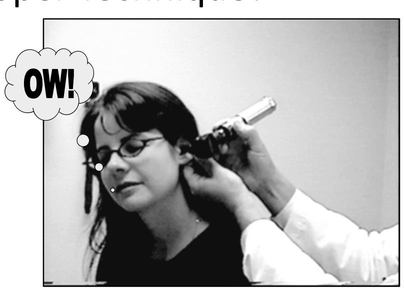
Proper Technique?



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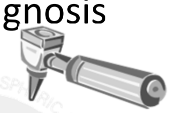
Technique is Everything

- Position both you & patient for comfort
- Hold Otoscope at balance point
- Use largest possible speculum for comfort
- Straighten the external canal
- Inspect to identify landmarks
- Verify optical characteristics of TM
- Get a good air-tight seal
- Check mobility

Middle Ear Diagnosis



- Pneumatic Otoscopy
  - Visualize TM mobility (compliance)
  - Proper use of Insufflator requires practice
  - Oral or Bulb
  - Never perform if a myringotomy is present
- Appearance of TM
  - Red? Bulging? Opaque? Sclerosed? Immobile?
  - Erythema alone is not a reliable sign

Pneumatic Otoscopy

Kim’s Good Ear

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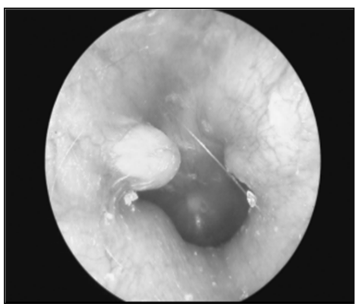
Bony Exostosis



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Otitis Externa (O.E.)

- more common in swimmers/divers
- most commonly bacterial
- 90% pain (otalgia), 10% itch
- pain with manipulation
- lymph node enlargement
- foul greenish-tinged discharge
- eczema, psoriasis, allergy & trauma

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Bacteriology of O.E.

- Pseudomonas species (99%)
- Staphylococcus Aureus
- Streptococcus
- Others
  - Proteus
  - Escherichia coli
  - anaerobes
  - Aspergillus (Otomycosis)

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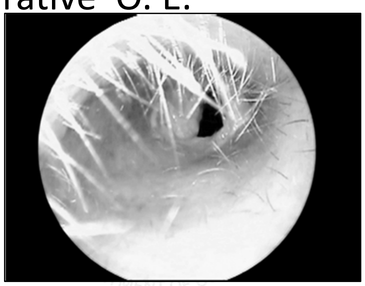
Suppurative O. E.



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Suppurative O. E.

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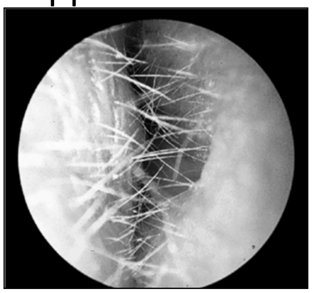
Clinical Appearance



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Clinical Features of O.E.

Pain?	Aggravated by chewing or manipulating Pinna
Tenderness?	Prominent at Tragus
Systemic sx?	Usually absent
Lymph nodes?	Often present
Swelling?	External Auditory Canal
Otorrhea?	Malodorous
TM?	Obscured but intact

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Atypical O.E.

C/C	Itch and muffled hearing
Tenderness?	Absent
Systemic sx?	Absent
Lymph nodes?	Absent
Swelling?	Absent
Otorrhea?	Absent
TM?	Coated with Exudate

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Atypical O.E. (?)

Think	"Wrong Diagnosis"
Allergy	Neomycin
Mastoiditis	Small perf
Foreign body	cotton
Irritant dermatitis	Inappropriate use of chemical to prevent OE
Infestation	Fly larva

Prevention

- Dr. Edley H. Jones (1971)
- Boric Acid in 90% ethyl alcohol (1924)
- Acetic Acid (5%) in 85% isopropyl alcohol
- 2% Acetic Acid solution = **pH of 3.0**
- 5 minute contact time = bactericidal effect
- Vosol (glacial acetic acid 2% in propylene glycol)
- Otic Domeboro (acetic acid - aluminum acetate)
- White Wine Vinegar = 4 to 6% Acetic Acid

Malignant Otitis Externa (Zebra)

- Occurs in diabetics, or in the **immunocompromised host**
  - HIV
  - chemotherapy
- Spreading Pseudomonas infection
- Severe, unrelenting ear pain
- 20% mortality rate

Treatments

- Cortisporin (10% Neomycin allergy) (neomycin/polymyxin B/hcz)
- Ofloxacin Otic sol .3% (Floxin Otic)
- Cipro HC Otic
- Clotrimzole for fungus
- Antistaph + antipseudomonal parenteral for necrotizing OE

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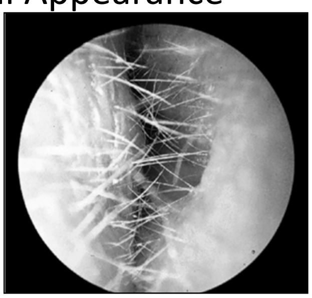
Clinical Appearance



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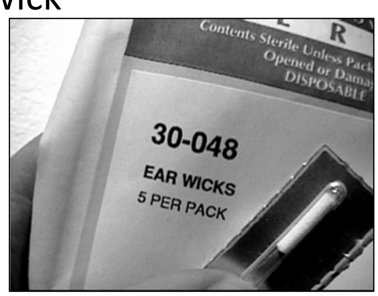
Otowick



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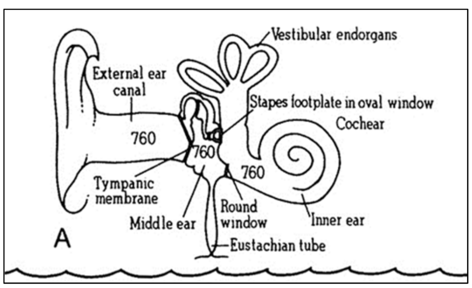
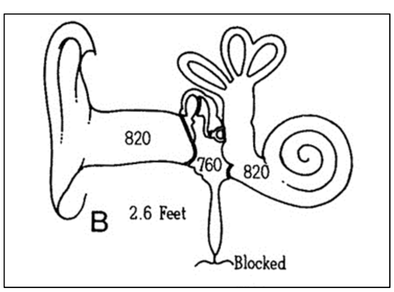
Barotrauma

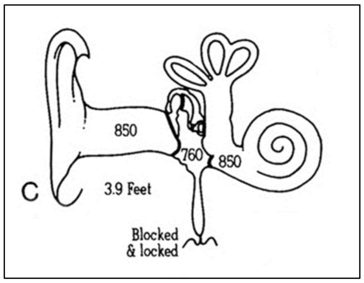
Sea Level pressures



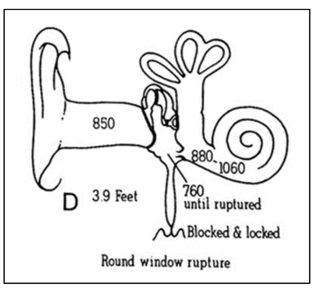
Descent to 2.6 fsw



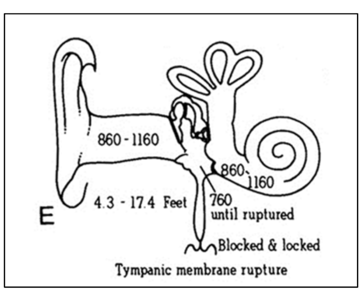
Descent to 3.9 fsw



Forceful Valsalva



Continued Descent



TEED Scale (Walter Teed, USN)

- 0 Symptoms without signs
- 1 Erythema along the handle of the Malleus
- 2 Erythema plus small splotches of hemorrhage
- 3 Gross hemorrhage within the TM
- 4 Free blood in middle ear
- 5 Perforation

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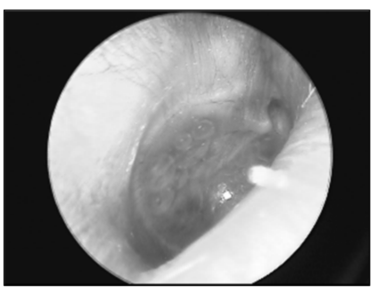
Middle Ear Effusion



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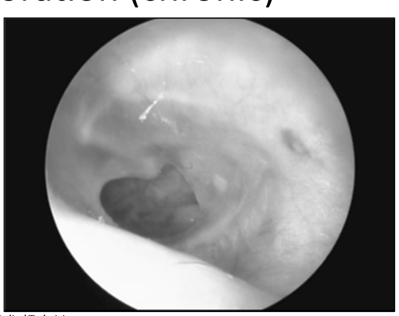
Perforation (chronic)



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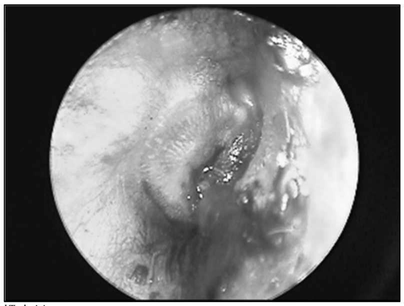
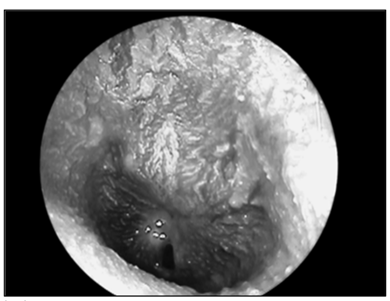
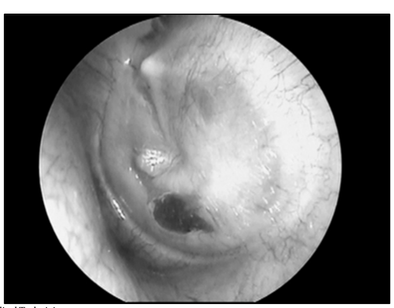
Perforation (acute)



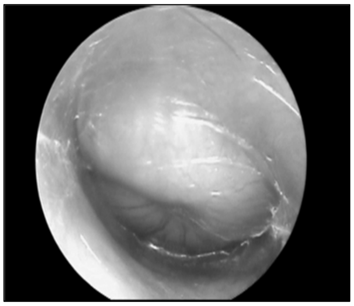
Perforation (traumatic)



Perforation (healed)



Barotrauma?



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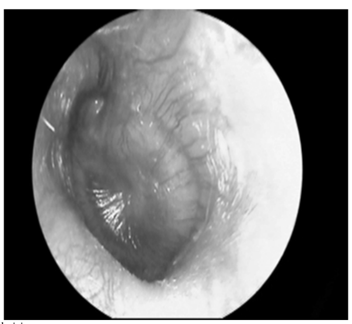
Barotrauma?



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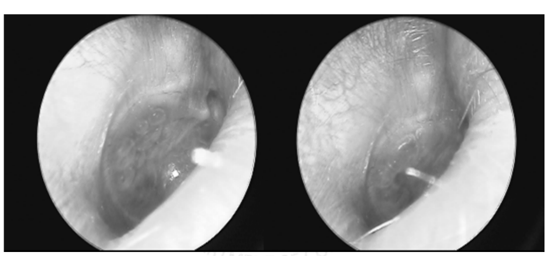
Video Otoscopy



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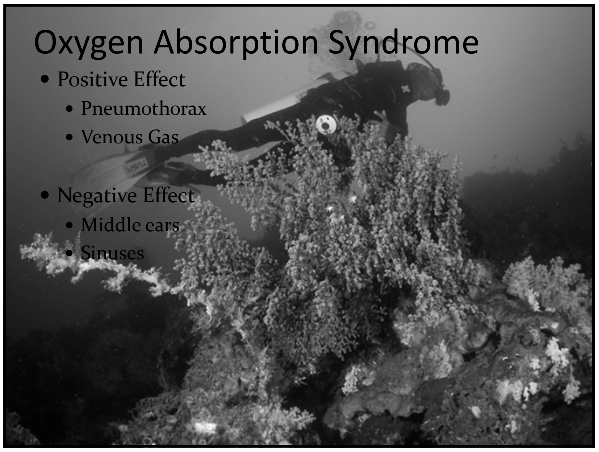
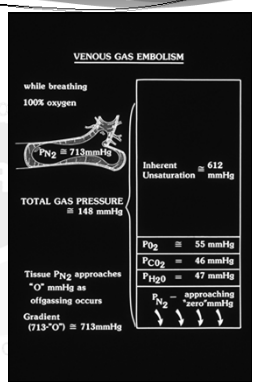
Oxygen Absorption Syndrome

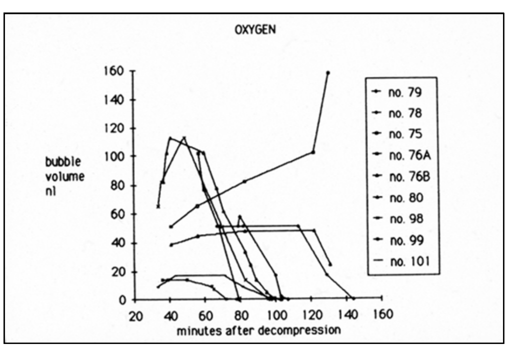
- Positive Effect
  - Pneumothorax
  - Venous Gas
- Negative Effect
  - Middle ears
  - Sinuses



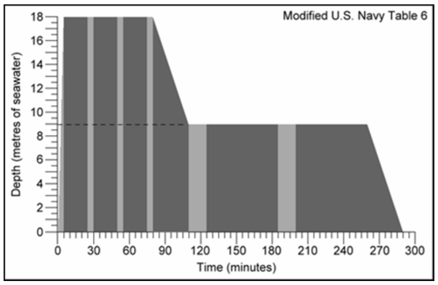
VENOUS BUBBLE
- 100% Oxygen
- Nitrogen washout
- Oxygen metabolized



Bubble Volume (in O2)



Oxygen Treatment



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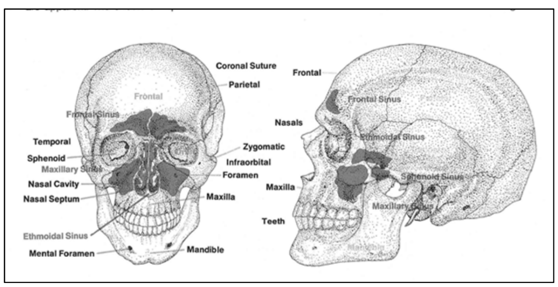
Sinus Barotrauma



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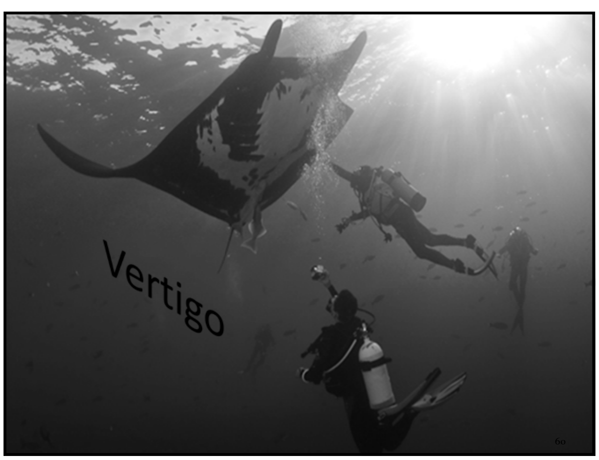

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Differential -Vertigo

- Barotrauma
- Hypoxia/Hypercapnia
- Nitrogen Narcosis
- Seasickness
- Alcohol Intoxication
- High Pressure Nervous Syndrome (HPNS)
- Contaminated Breathing Gas
- Unequal Caloric Stimulation
- Unequal Vestibular Stimulation
- Oxygen Toxicity
- Inner Ear DCI (8th of 25)
- Hyperventilation
- BPPV

Cochleovestibular Barotrauma

Synonyms

- Round (?) Window Rupture
- Labyrinthine Fistula
- Perilymphatic Fistula

117 Injured Inner Ears

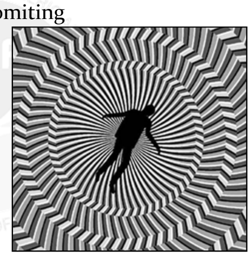
- 47 pure cochlear damage (symptoms in 88%)
- 14 pure vestibular damage (symptoms in 70%)
- 56 combined injury

Treatment

- Bed rest
- Elevation of head
- No straining
- No conclusive tests for fistulae
- Surgical exploration if fistulae in suspected
- Prognosis is best after surgery
- Steroids (?)
- No diving for 3 months

Alternobaric Vertigo

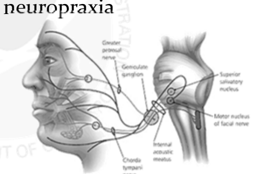
- "le syndrome de Lundgren" 1965
- Objective vertigo, nausea, vomiting
- Most common on assent
- Unilateral barotrauma
- Asymmetrical pressure stimulation of vestibular apparatus



Alternobaric Facial Palsy

(AKA: Facial Baroparesis)

- Defects in bony canal of Facial Nerve through the temporal bone in the middle ear
- Nerve exposed to pressures exceeding capillary pressure lead to ischemic neuropraxia
  - fullness, plugging
  - mouth weakness
  - cannot close eye
  - decreased taste



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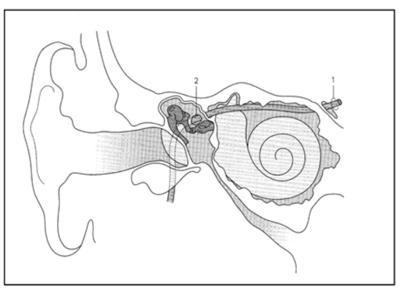
Defects in Temporal Bone (57%)



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Case Report

- 24 y/o student diver with minor URI
  - slight sinus and ear squeeze on descent
  - 30 ft for 40 minutes in KM Superlite
- Upon surfacing was in obvious agony
  - forehead grotesquely deformed
- Transported to nearest hyperbaric unit VM
  - examining emergency physician found nothing wrong
  - all symptoms spontaneously disappeared

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Pneumosinus Dilatans

- Nightmare reverse block
- Acute painful expansion of the aerated frontal sinus
- Visible, distressing forehead bossing
  - one-way-valve
  - ball-valve
  - check-valve
  - trap-door

  } all equivalent terms
- Acute barotrauma induced pressurization
  - lasts minutes to hours

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Ear Barotraouma

- Most frequent diving injury
- Common in novice divers
- Poor understanding of equalization technique
- Ear damage (Barotrauma) is…

PREVENTABLE

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Essentials

- Recognize "Ear Fear"
- Recognize a "Dysfunctional Valsalva"
- Teach "Eustachian Tube Awareness"
- Learn to "Calibrate Pressurization Effort"

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What is "Ear Fear"?

- Pressure perceived as *"uncomfortable"*
- Childhood pain ⇨ adult fear
- Retrograde tear duct inflation
- Confusion over instructions

How hard is too hard?

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Calibrating Pressurization Effort

- *Watch The Nose Inflate!*
- Fingers low on nose
- Palpate firmness of inflation and compare it to your own pressurization effort
- Asses effectiveness of pressurization
- Tailor the "compensation" technique to the individual

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Eustachian Tube Awareness

- Listen to the sounds the ear makes
- Tubal opening "crackle" (tiny sound)
- Middle ear pressurization "BLOOP"

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Pressurization Techniques

- Valsalva Maneuver (1704)
- Frenzel Maneuver (1932)
- Combination Techniques (1950s)
  - Pressurize and swallow
  - Pressurize and yawn

Assessing Equalization Effort

- The Doc's Technique:
- Watch The Nose Inflate!
- Occluding fingers low on nose
- Palpate firmness of inflation
  and compare it to your own equalization effort

Antonio Valsalva

- Pinch nostrils closed
- Increase pressure in chest
- Cheeks tight, not puffed out
- Start from the surface
- Brisk upstroke, hold for a second, let go
- Repeat as needed all the way down

Dr. Herman Frenzel

Luftwaffe Commander, 1938
(Marcante-Odaglia in Italy)

- "The Throat Piston"
- Close vocal cords
- Pinch nostrils closed
- Raise the larynx and back third of tongue
- Feel "Adams Apple" elevate

Advantages

- Does not adversely effect blood flow
- Independent of respirations
- Can be performed with mouth open
- Easy to teach and practice

"Bobbing Adams Apple"

Béance Tubaire Volontaire

- First described by G. Delonca, 1980
  - La plongée Santé-Sécurité
- **Distilled Yawn or Modified Retching** (soft palate maximally elevated)
- Tongue tensed (canoe shaped) or -
- Tongue tensed, curling it back, brushing the roof of mouth in an attempt to touch the soft palate.
- Uvula tipped forward (practice in mirror)
- Control the Levator Palatini & Tensor Palatini

Roydhouse

- Another way to learn BTV
- Raise up and tilt Uvula forward
- Tense muscles of tongue
- Jaw thrust (blow smoke rings)

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Tubal Aerobics

- Nasopharyngeal-eustachian exercises
- Reinforce and synchronize anatomical structures
- Impart awareness, competency & control
- Tongue - Jaw – Soft palate – Chest
- Breathing – Swallowing – Vocalizing
- 10 – 15 minutes /day until proficient

NOAA Diving Medical Technician 2015 Pelizzari,U. and Tovaglieri, S., *Manual of Free Diving*, Idelson-Gnocchi, 2004 80

Many Methods

- Tailor the technique
- Pressurization methods work best for the novice
- Teach "Eustachian Tube Awareness"
- Begin middle ear pressurization **On the Surface -PRIOR to descent**
- Be more specific than just saying "Early and Often"

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Summary

- "Ear Fear" think Dysfunctional Valsalva
  - pressure never reaches the nasopharynx
  - pressure to low to open the e tube
- Watch the nose inflate
- Bob your Adams Apple
- Pre-pressurize prior to descent
- Never pressurize on ascent

Hearing Loss

Hearing Loss

- Conductive Hearing Loss
- Sensory Neural Hearing Loss
- Foreign body obstruction
- Occupational
  - acoustic trauma
  - barotrauma
- Selective hearing loss

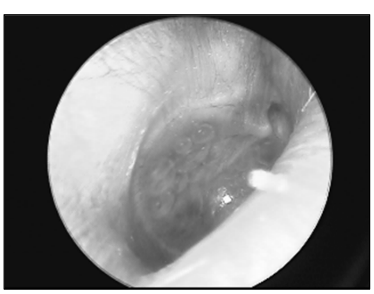
Selective Hearing Loss

- Teenage adjustment disorder
- Spousal adjustment disorder
  - male predominance
- Patient denial

Conductive **H**earing **L**oss

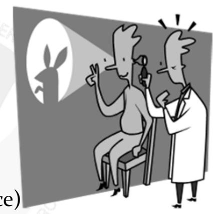
- Causes rarely severe or life threatening
- Detected by a lateralized Weber Test
- OCD (Ossicular discontinuity)
- Otosclerosis
- Middle Ear Effusion
  - serous otitis
  - mucoid otitis "glue ear"

Middle Ear Effusion



Sensory-**N**eural **H**earing **L**oss

- Cochlear Barotrauma
- Presbycusis
- Ménière's disease
- Brain Lesion
- Tinnitus: acoustic trauma
- Inherited disorder of hearing
- Acoustic Neuroma (1% incidence)
- Ototoxic drugs or renal failure



Bedside Testing

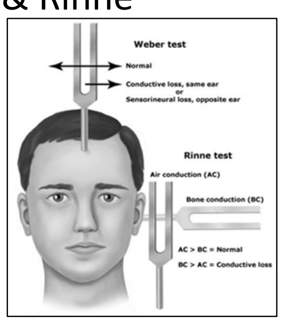
Weber's Test

- Tuning Fork to midline forehead or teeth
- WNL: Sound radiates to both ears equally
- ABN: Sound lateralizes to one ear
  - Ipsilateral = Conductive
  - Contralateral = Sensorineural

Rinne's Test

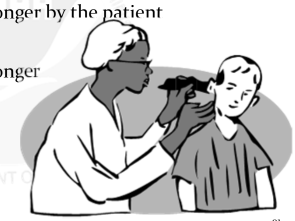
- Bone Conduction
  - Tuning Fork on Mastoid
- Air Conduction
  - Patient indicates when the sound ceases
  - Fork placed in front of ear
- WNL: AC>BC
- ABN: BC>AC

Weber & Rinne



Schwabach's Test

- Compares bone conduction of patient to that of normal examiner
- Conductive HL
  - The tone is heard longer by the patient
- Sensory-neural HL
  - The tone is heard longer by the examiner



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ENT Contraindications (verbose)

- **Recurrent otitis externa**
- **Obstruction of external aud. canal**
- **Eustachian tube dysfunction**
- **Recurrent otitis media or sinusitis**
- **History of TM perforation**
- **History of tympanoplasty**
- **History of mastoidectomy**
- **Significant hearing impairment**
- **Facial nerve paralysis**
- **Full prosthedontic devices**
- **History of mid-face fracture**
- **Unhealed oral surgery sites**
- **History of head + neck radiation**
- **History of TMJ dysfunction**
- **History of round window rupture**
- **Monomeric TM**
- **Open TM perforation**
- **Tube myringotomy**
- **History of stapedectomy**
- **History of ossicular chain surgery**
- **History of inner ear surgery**
- **Facial nerve paralysis secondary to barotrauma**
- **Inner ear disease**
- **Uncorrected upper airway obstruction**
- **Laryngectomy**
- **Tracheostomy**
- **Uncorrected laryngocele**
- **History of vestibular decompression**

NOAA Diving Medical Technician 2015 92

ENT Contraindications (succinct)

- Not susceptible to barotrauma
- No disease present that diving could make worse

Moon, RE

NOAA Diving Medical Technician 2015 93

How to Determine Fitness to Dive

"If you don't have gills, the term 'fitness to dive' is a misnomer" - Andy Veale MD

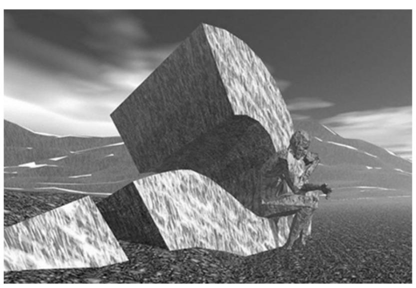
"It's probably more important to ask if someone has ever run out of gas on the freeway than to ask about most medical conditions" - Tom Neuman MD

- What incremental risk is acceptable?
- Where should the threshold for qualification be set?

Adapted from Moon, RE

NOAA Diving Medical Technician 2015 94

Questions?



Neurologic Exam

CDR Joel Dulaigh
NOAA Diving Medical Officer

1

Global View

- The purpose of an on-site neurological assessment
- The seven areas evaluated as part of an on-site neurological assessment
- Taking a dive history
- How to perform an on-site neurological assessment

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
How Many Dives in Last 48 Hours ____ Time In ____ Time Out ____ Maximum Depth ____ Safety Stop ____ Bottom Time ____

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.

2

Introduction

- Approximately two-thirds of divers with decompression illness have evidence of damage to the nervous system
  - Signs are often vague and can go unrecognized
  - Can be dismissed as insignificant or not dive-related

3

Introduction

- The neurological exam is a skill that requires practice and is not routinely used by many providers
- Information gathered helps the dive physician understand the extent of the injury and also helps direct the definitive care
- Non-invasive procedure that can be easily done in the field
- Can be done bare handed with ordinary items
- Is one of the most important skills to learn for those in diving medicine

4

Areas to be assessed

- Seven (7) areas to be evaluated:
  - Mental status & level of consciousness
  - Vital signs
  - Coordination
  - Cranial nerves
  - Skin sensation
  - Strength
  - Reflexes

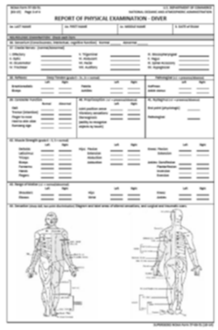
5

Field Neurological Exam Form

- This form is used by NOAA divers for documenting findings
- Repeat exam periodically to determine if a diver's condition is the same, improving, or getting worse

Physical Exam Neuro Page

- This form is page 2 of the NOAA Report of Physical Exam.
- Completed for initial and periodic physical exams.



Mental Status

MENTAL STATUS/STATE OF CONSCIOUSNESS
(Circle one)
A = Awake and alert — Knows: person ___ place ___ time___ year ___ — Identify objects? _____
V = Responsive to voice — Can add nickel, quarter, and dime? ____ — Glasgow Coma Scale score: ______
P = Responsive to pain — Recite 3 unrelated objects after wait? _____
U = Unresponsive — Speech: ___ normal ___ abnormal

- Test of cognitive function
- Best determined from first interview with individual
- Mental function consist of two parts:
  - Mental status
  - Level of consciousness

8

Mental Status

- Includes the diver's level of consciousness, orientation to person, place and time, along with memory, speech, arithmetic skills and ability to comprehend language
- Also includes Glasgow Coma Scale
- Many of these tests can be performed during your initial conversation with the diver
- Most injured divers exhibit normal mental function

9

Evaluating Mental Status

- Begin your mental status assessment by simply talking to the diver
- Even though a diver appears alert, the answers to these questions may reveal confusion.

10

Evaluating Mental Status

Consciousness

- Mark the diver's status on your slate using the acronym

A = Awake and alert

V = Responsive to verbal stimuli

P = Responsive to pain

U = Unresponsive

Evaluating Mental Status

Speech and Language

- Judge the diver's use of speech and language
- Determine whether he is understandable and can follow directions

12

Evaluating Mental Status

Alert to Place and Time

- Ask the injured diver if he knows what time it is, what day it is
- Ask the date and year
- Ask the diver where he is
- Ask him if he knows what state he is in
- Ask if the diver knows who he is and who you are

13

Evaluating Mental Status

Judgment

- Ask the diver if he knows what is happening or why he is here

Short-term Memory

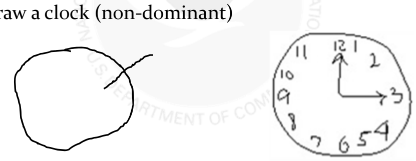
- To test the diver's short term memory name three objects for him (e.g., truck, dog, flag).
- A couple of minutes later, ask him to repeat those three objects back to you

14

Evaluating Mental Status

Parietal Lobe Function

- Calculations (dominant)
  - Count backwards from 100 by 7's
  - How much is a nickel, dime, and a quarter?
- Draw a clock (non-dominant)



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Glasgow Coma Scale

- The Glasgow Coma Scale is the most widely used scoring system used in quantifying level of consciousness following traumatic brain injury.
- It is used primarily because it is simple, has a relatively high degree of interobserver reliability and because it correlates well with outcome following severe brain injury.

GLASGOW COMA SCALE

I. Motor Response
6 - Obeys commands fully
5 - Localizes to noxious stimuli
4 - Withdraws from noxious stimuli
3 - Abnormal flexion, i.e. decorticate posturing
2 - Extensor response, i.e. decerebrate posturing
1 - No response

II. Verbal Response
5 - Alert and Oriented
4 - Confused, yet coherent, speech
3 - Inappropriate words, and garbled phrases consisting of words
2 - Incomprehensible sounds
1 - No sounds

III. Eye Opening
4 - Spontaneous eye opening
3 - Eyes open to speech
2 - Eyes open to pain
1 - No eye opening

Glasgow Coma Scale = I + II + III. A Coma Score of 13 or higher correlates with a mild brain injury, 9 to 12 is a moderate injury, and 8 or less a severe brain injury.

16

Glasgow Coma Scale

- Using the Glasgow Coma Scale, determine the best score for motor, verbal, and eye opening responses
- Sum of the numeric scores of each of the categories to determine the final score
  - 13 or higher indicates mild brain injury
  - 9 – 12 is a moderate injury
  - 8 or less a severe brain injury

Glasgow Coma Scale

Eye Opening	
Spontaneously	4
To verbal command	3
To painful stimulus	2
None	1

Verbal Response	
Talking/Oriented	5
Confused/Disoriented	4
Inappropriate words	3
Incomprehensible words	2
None	1

Motor Response	
Obeys commands	6
Localizes to pain	5
Withdraws from pain	4
Abnormal Flexion	3
Abnormal extension	2
None	1

17

Vital Signs

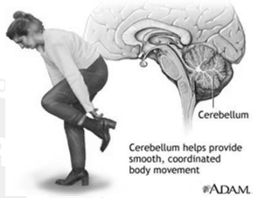
VITAL SIGNS Pulse/min ____ Respirations ____ Blood Pressure ____ Temp (warm, cool, normal) ______

- It is important to determine the status of a person's basic life-sustaining condition
- Vital signs consist of 4 parameters:
  - Pulse per minute
  - Blood Pressure
  - Respirations per minute
  - Temperature

18

Coordination

- Test of cerebellar and inner ear function
- Balance is evaluated based on the ability to stand and walk with or without assistance
- Coordination is evaluated using a series of directed movements



COORDINATION (Normal/Abnormal)

Walk: __________
Heel-to-toe: __________
Romberg: __________
Finger-to-nose: __________
Heel-shin slide: __________
Rapid movement: __________

19

Coordination

Walking

- Have the diver walk forward about 10 feet while looking straight ahead first with a normal gait and then repeat with heel-to-toe
- Note whether movements are smooth and if the diver can maintain balance without looking down or holding on
- Be prepared to catch the diver if he starts to fall

20

Coordination

Walking

- Have the diver walk up on their t then walk on heals.
- Note whether movements are smooth and if the diver can mai balance without looking down o holding on
- Be prepared to catch the diver if starts to fall

21

Coordination

Romberg

- Eyes closed, feet together, arms extended in front, head back with slight push from front/back & side to side
- Be prepared to catch the diver if he starts to fall
- Abnormal results if patient cannot maintain balance

22

Coordination

Finger-Nose-Finger

- Ask the diver to move his index finger back and forth rapidly between his nose and your finger held approximately 18 inches from his face
- Have him attempt to do it again with his eyes closed

23

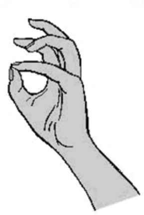
Coordination

Heel-shin slide

- Standing patient runs heel of foot down shin of other leg then repeats with other foot and leg

Rapid Alternating Movement

- Touch the thumb to each finger and back several times



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Cranial Nerves

- Twelve pairs of nerves emanate from the skull
- They control the various senses and muscles of the face such as the eyes, ears, mouth, tongue, throat and neck

CRANIAL NERVES (Normal/Abnormal)
Sense of smell (I) ________
Vision/visual field (II) ________
Eye movements, pupils (III, IV, VI) ________
Facial sensation, chewing (V) ________
Facial expression muscles (VII) ________
Hearing (VIII) ________
Upper mouth, throat sensation (IX) ________
Gag and voice (X) ________
Shoulder shrug (XI) ________
Tongue (XII) ________

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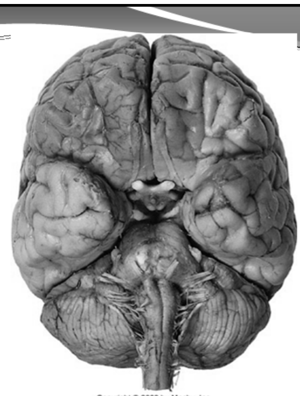

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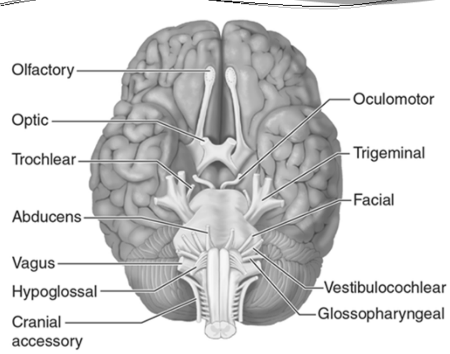
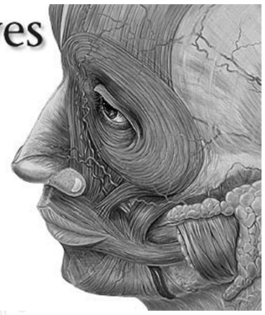


Cranial Nerves

- I Olfactory
- II Optic
- III Oculomotor
- IV Trochlear
- V Trigeminal
- VI Abducens
- VII Facial
- VIII Vestibulocochlear (Auditory)
- IX Glossopharyngeal
- X Vagus
- XI Accessory (Spinal Accessory)
- XII Hypoglossal



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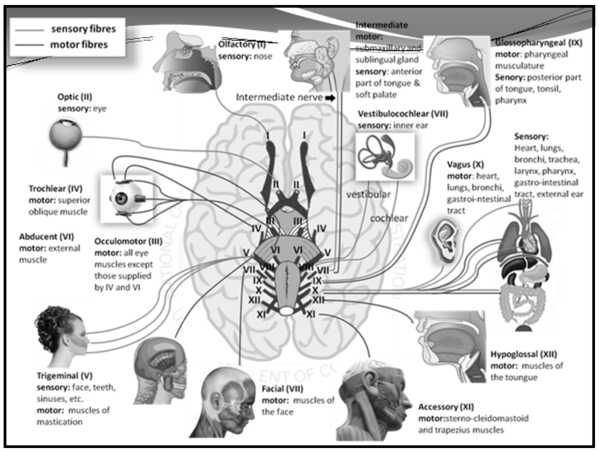


CN II

Optic

- Visual fields
- Acuity
- Pupillary light reflex
  - (also CN III)

30

CN III, IV, & VI
Occulomotor, Trochlear, and Abducent

Eye Movements/Pupils

- Hold your finger three feet in front of the diver
  - Move your finger right and left, up and down
  - Record any direction the diver cannot follow your finger
  - Hold finger at outer edge to check for nystagmus (involuntary movement of either eye)
- Also check to see if the pupils are equal and reactive to light

31

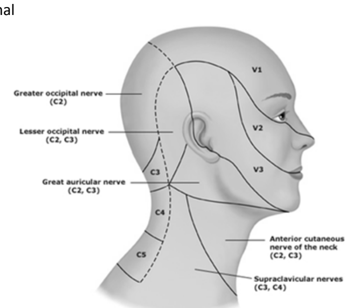
CN V
Trigeminal

Facial Sensation/Chewing

- Touch the divers face in three different locations to assess differences in sensation
- Have diver repeatedly clench and unclench teeth and simulate chewing motion

32

CN V
Trigeminal



CN VII

Facial

Facial Expression Muscles

- To evaluate facial control have the diver close his eyes, smile, wrinkle forehead, show teeth, and swallow
- The face should appear the same on both sides
- Indicate any weaknesses or droopiness in the face

34

CN VIII

Auditory (Vestibulocochlear)

Hearing

- Test the diver's hearing by holding your hand about 12 inches from the diver's ear and rubbing your thumb and finger together
- Determine if hearing is symmetrical on both sides or if one side is reduced
- If the surroundings are noisy ask bystanders to be quiet and turn off unneeded equipment

35

CN IX

Glossopharyngeal

- Upper Mouth/Throat Sensation
  - Have the diver stick out tongue and say "aah"
  - Check to see that the uvula rises

36

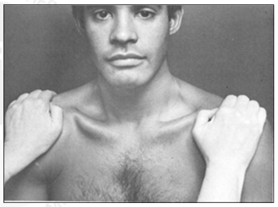
CN X
Vagus

- Gag and Voice
  - Listen to the divers voice for normal speech and for any change in tone
  - Note any abnormalities
  - Generally not necessary to test gag reflex in a screening exam
  - May use a CTA or tongue depressor to elicit gag if suspicious of insult

37

CN XI
Spinal Accessory

- Shoulder Shrug
  - While seated, apply downward pressure to both of the diver's shoulders
  - Ask the diver to shrug their shoulders
  - Note any deficiency in strength



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CN XII
Hypoglossal

- Tongue movement
  - Have patient stick out their tongue
  - Move it side to side
  - May also have them push tongue against inside of each cheek

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Motor Strength

- Testing of muscular-skeletal system
- All muscle groups need to be tested and compared bilaterally

STRENGTH
Graded 0-5:
0 = Paralysis (no motion possible)
1 = Profound weakness (trace of muscle contraction)
2 = Severe weakness (muscle contraction but not against gravity)
3 = Moderate weakness (can overcome gravity but not resistance)
4 = Mild weakness (able to resist slight force)
5 = Normal (equal strength, able to resist force)

Upper body:	Deltoids:	L ______	R ________
	Latissimus:	L ______	R ________
	Biceps:	L ______	R ________
	Triceps:	L ______	R ________
	Forearms (grip):	L ______	R ________
	Hands (finger spread):	L ______	R ________
Lower body:	Hips - Flexion:	L ______	R ________
	Extension:	L ______	R ________
	Abduction (spread):	L ______	R ________
	Adduction(squeeze):	L ______	R ________
	Knees - Flexion:	L ______	R ________
	Extension:	L ______	R ________
	Ankles - Doriseflexion:	L ______	R ________
	Plantarlfexion:	L ______	R ________

40

Motor Strength

- Represent in one of three ways: numbness, weakness or paralysis
- Compare one side of the body with the other
  - Decompression Illness can affect both sides of the body simultaneously, the effects are rarely the same on both sides
- Any sign of weakness or paralysis, no matter how slight, should prompt you to seek immediate emergency medical assistance and professional medical evaluation

41

Motor Strength

- Graded on a scale of 0 to 5:
  - 0 = Paralysis (no motion possible)
  - 1 = Profound weakness (trace of muscle contraction)
  - 2 = Severe weakness (muscle contraction but not against gravity)
  - 3 = Moderate weakness (can overcome gravity but not against resistance)
  - 4 = Mild weakness (able to resist slight force)
  - 5 = Normal (equal strength, able to resist force)

42

Motor Strength

- Areas to be evaluated include the shoulder, biceps, triceps, hands, hips, legs and feet
- For each test, have the diver push/pull against resistance you provide (strength should be approximately equal on both sides)
- Record your findings graded as 0 through 5
- Testing of extremity strength is divided into two parts:
  - Upper body
  - Lower body

43

Motor Strength

Shoulders

- Bring the elbows level with the shoulders, hands level with the arms and touching the chest
- Instruct the diver to resist while you push down and then pull up

44

Motor Strength

Bicep

- Steady the divers arm and pull down against the hand

Tricep

- The diver should attempt to push you away

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Motor Strength

Finger Spread

- Test the diver's ability to spread his hands by providing resistance against the side of his index finger as he attempts to spread his fingers

Grip

- Test the diver's grip strength by having him grip one or two of your fingers in each hand and squeeze

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Motor Strength

Hip Flexors

- Push down on the diver's bent leg so he is resisting at the hip

Quadriceps and Hamstrings

- Test the diver's quadriceps and hamstring the same way you did the biceps and triceps

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Motor Strength

- To test the divers' foot strength, have him flex his foot at the ankle both up and down, against your resistance

48

Reflexes

Reflexes

REFLEXES
Grade: (0-absent, 1-hypoactive, 2-normal, 3-hyperactive)

Biceps: L______ R______ Forearm: L_______ R_______ Knees: L______ R_____ Ankles: L_______ R_______

- Test to determine if the patient's response to reflex stimulation is normal, absent, hypoactive (deficient), or hyperactive (excessive)
- Strike tendon with an equal, light force and with sharp, quick taps
  - Biceps
  - Forearm
  - Knee
  - Ankle

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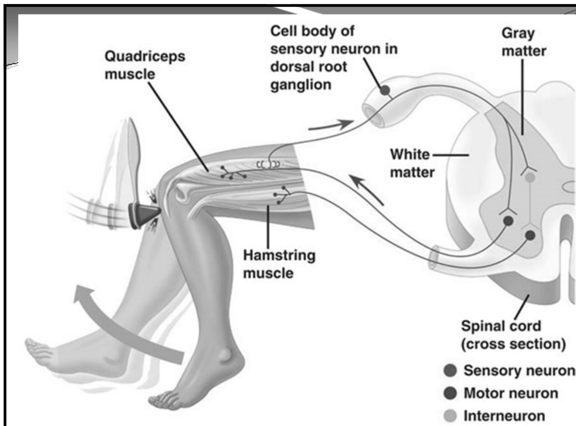

Reflexes

- Biceps
  - Examiner holds patient's elbow with patient's hand resting on examiner's forearm
  - Patient's elbow bent and arm relaxed
  - Examiner places thumb on patient's biceps tendon
  - Tap thumb with hammer and feel for muscle contraction

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Reflexes

- Brachial-radialis
  - Hold the patients arm or relax it on their thigh
  - Gently tap the forearm directly with the reflex hammer

53

Reflexes

- Knees
  - Patient sits with feet off deck
  - Tap patient's knee just below kneecap on tendon and look for contraction of quadriceps and movement of lower leg

54

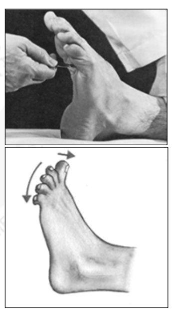
Reflexes

- Ankles
  - Patient sits with feet off deck
  - Place slight pressure on patient's toes to stretch the Achilles' tendon
  - Feel for contraction of toes as the Achilles' tendon shortens

55

Reflexes

- Babinski
  - With an object such as a key, stroke the lateral aspect of the sole from heel to the ball of the foot, curving medially across the ball
  - Normal = toe flexion
  - Abnormal = toe extension



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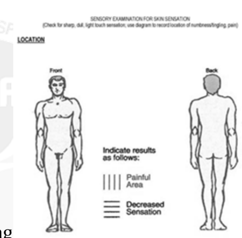
Skin Sensation

- Four of the more common warning signs of DCI are:
  - Pain, defined as perception without stimulus,
  - Numbness that can be confirmed during the examination,
  - Paralysis
  - Tingling, defined as a feeling of pins and needles with a decrease in normal sensation



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Skin Sensation

- Using a light touch first, slowly scan the body
  - Have the diver close his eyes during this procedure
- Determine if there any areas of altered sensitivity
- The diver should identify each area as you move down the body
  - The diver should confirm the sensation, or lack of it, in each area before you move to another area

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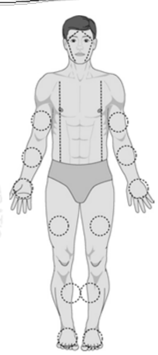
Skin Sensation



- Touch the upper arms along the biceps and then the forearms
- Then test both hands, on the back of the hand and the palm
- Scan the diver's torso from his collar bones to his hips to determine if there are any areas with altered sensitivity

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Skin Sensation

- From there, move to the front of the diver's thighs and then down to the inside of his calves
- Lastly, check the top of the diver's feet
- Repeat the same examinations using a sharp object, such as a pin or a broken tongue depressor

60

Dermatomes

- Dermatomes represent specific regions of nerve reception of sensory impulses
- Abnormally functioning dermatomes provide important clues about injury to the spinal cord or specific spinal nerves.
- If a dermatome is stimulated but no sensation is perceived, it can be inferred that the nerve to that specific dermatome has been injured.

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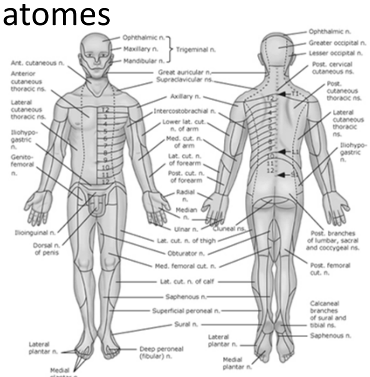
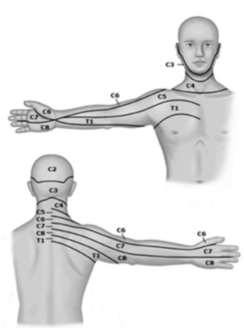
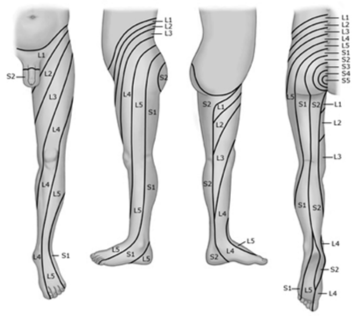
Dermatomes



Dermatomes



Dermatomes



Key Points

- This examination may provide valuable information
- Any abnormal results, suspect injury to the central nervous system
- Record all findings from the exam and review them to see if you have missed any tests
- The diver's condition may prevent the performance of one or more of these tests
- Record any omitted test and the reason

65

Key Points

- If you determine there is a likely dive injury, immediately begin oxygen first aid
  - Remember, you will not harm the diver by providing oxygen first aid in the event the problem does not turn out to be dive-related
- Activate your emergency plan

66

Key Points

- Repeat this examination frequently while awaiting assistance; how often depends on nature and severity of the injury. Ten to fifteen minute intervals is a good starting point.
- This will be helpful to determine if any change in the diver's condition occurs
- Report the results to the emergency medical personnel responding to the call

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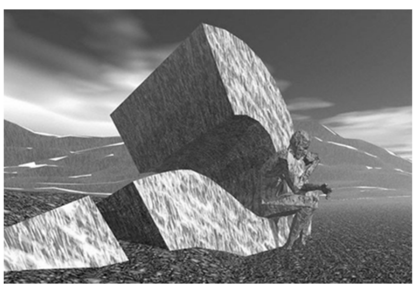
Questions?



Gastrointestinal Intubation

Nasogastric tubes

NOAA Diving Medical Technician 2015

Overview

- Types of Tubes
- Indications for their use
- How to insert NG tubes
- Complications of NG tubes
- Enteral Feedings
- Indications and Complications.
- Gastrostomy

Types of Tubes

- Short tubes: passed through the nose into the stomach
  - Levin tube: range in size from 14 to 18 Fr, single lumen made of plastic or rubber with holes near the tip.
  - Gastric Sump (Salem): is radiopaque, clear plastic double lumen

Types Cont.

- Medium Tubes: tubes are passed through the nose to the duodenum and the jejunum. Used for feeding
  - Polyurethane or silicone rubber feeding tubes have a narrower diameter (6 to 12fr) and require the use of a stylet for insertion
- Long tubes: passed through the nose, through the esophagus and stomach into the intestines. Used for decompression of the intestines.

Example of Salem Sump

Indications for GI Intubation

- To decompress the stomach and remove gas and fluid
- To lavage the stomach and remove ingested toxins
- To diagnose disorders of GI motility and other disorders
- To administer medications and feedings
- To treat an obstruction
- To compress a bleeding site
- To aspirate gastric contents for analysis

Intubating the client with an NG tube

- Assessment:
  - Who needs an NG:
    - Surgical clients
    - Ventilated client
    - Neuromuscular impairment .
    - Clients who are unable to maintain adequate oral intake to meet metabolic demands.
  - Assess patency of nares.

Assessment cont.

- Assess client's medical history:
  - Nosebleeds
  - Nasal surgery
  - Deviated septum
  - Anticoagulation therapy
- Assess client's gag reflex.
- Assess client's mental status.
- Assess bowel sounds.

Planning

- Gather equipment:
  - 14 or 16 Fr NG tube
  - Lubricating jelly
  - PH test strips
  - Tongue blade
  - Flashlight
  - Emesis basin
  - Catheter tipped syringe
  - 1 inch wide tape or commercial fixation device
  - Suctioning available and ready

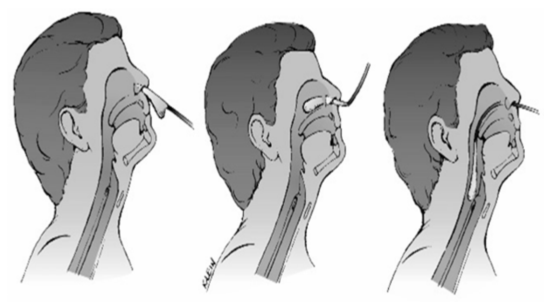
Planning Cont.

- Explain procedure to client
- Position the client in a sitting or high fowlers position. If comatose-semi fowlers.
- Examine feeding tube for flaws.
- Determine the length of tube to be inserted.
- Measure distance from the tip of the nose to the earlobe and to the xyphoid process of the sternum.
- Prepare NG tube for insertion.

Measurement

Implementation

- Wash Hands
- Put on clean gloves
- Lubricate the tube
- Hand the client a glass of water
- Gently insert tube through nostril to back of throat (posterior nasopharynx). Aim back and down toward the ear.
- Have client flex head toward chest after tube has passed through nasopharynx



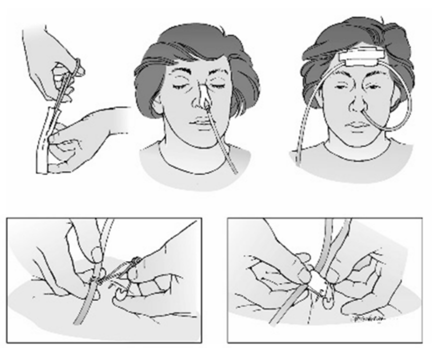
Implementation Cont.

- Emphasize the need to mouth breathe and swallow during the procedure.
- Swallowing facilitates the passage of the tube through the oropharnyx.
- When the tip of the tube reaches the carnia stop and listen for air exchange from the distal end of the tube. If air is heard remove the tube.
- Advance tube each time client swallows until desired length has been reached.
- Do not force tube. If resistance is met or client starts to cough, choke or become cyanotic stop advancing the tube and pull back.

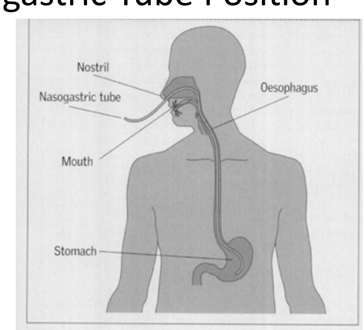
Implenentation Cont.

- Check placement of the tube.
  - X-ray confirmation
  - Testing pH of aspirate
- Secure the tube with tape or commercial device

NG Tube Insertion



Nasogastric Tube Position



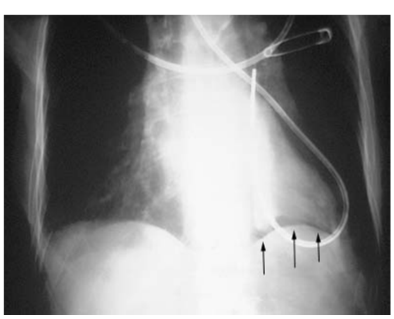
Evaluation

- Observe client to determine response to procedure.
- ALERTS!!! Persistent gagging – prolonged intubation and stimulation of the gag reflex can result in vomiting and aspiration
  - Coughing may indicate presence of tube in the airway.

Evaluation Cont.

- Note location of external site marking on the tube
- Documentation
  - Size of tube, which nostril and client's response.
  - Record length of tube from the nostril to end of tube
  - Record aspirate pH and characteristics

X-ray of misplaced NG tube



Testing Placement

- Wash hands and put on clean gloves
- Draw up 30cc of air into the syringe and attach to end of the NG tube. Flush tube with 30cc of air prior to attempting to aspirate fluid. Draw back on the syringe to obtain 5 to 10 cc of gastric aspirate.
- If unable to aspirate:
  - Advance tube – may be in air space above aspirate level
  - If intestinal placement suspected (pH 4-6) withdraw tube 5 to 10 cm
  - Have client lie on his/her left side wait 10-15 mins and attempt aspiration again.

Testing Placement cont.

- Observe appearance of aspirate:
  - From client with enteral feeding – appearance of curdled enteral feed
  - From nasointestinal – bile stained
  - From stomach (non feed)– green, tan, bloody, brown.
  - Pleural fluid – pale yellow and serous
  - Gently mix aspirate in syringe

Testing Placement cont.

- Note:
  - In a study by Metheny et al (1994) the gastric aspirate of 880 clients were examined:

    > gastric aspirate ranged in color from green to yellow, tan/brown or bloody

    > respiratory aspirate was described as tan or yellow/green (Best 2005)

Testing Placement Cont.

Measure pH of aspirated GI contents by dipping pH strip into the fluid or by applying a few drops of the fluid to the strip. Compare the color of the strip with the color on the chart.

- Gastric fluid from a client who has fasted for at least 4 hours usually has a pH range from 1 to 4 but may be increased if the client is receiving acid inhibiting medications (pH 4-6)

Testing Placement Cont.

- Fluid from nasointestinal tube of fasting client usually has a pH greater than 6. intestinal contents are less acidic than stomach.
- Clients with a continuous tube feed may have a pH of 5 or higher.
- Pleural fluid from the tracheubronchial tree is generally greater than 7.
- National Patient Safety Association(2005a) recommend a pH of less than 5.5 feedings can be initiated (Best, 2005)

Testing Placement Cont.

- Measure the length of the tube from nostril to tip.
- If after repeated attempts, it is not possible to aspirate fluid from a tube that was originally established by x-ray examination to be in the desired position and there are NO risk factors for dislocation, tube has remained in original position and the client is NOT experiencing any difficulty you may assume the tube is correctly placed.

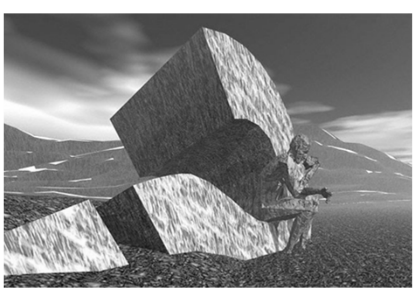
Responsibilities

- Identify signs and symptoms of inadvertent respiratory migration.
- Identify conditions that increase the risk for spontaneous tube dislocation from the intended position (retching, vomiting, nasotracheal suctioning, severe coughing)

Enteral Nutrition

- What is it:
  - The administration of nutrients directly into the GI tract. The most desirable and appropriate method of providing nutrition is the oral route, but this is not always possible.
  - Nasogastric feeding is the most common route
  - Nurses are the main healthcare professional responsible for intubation

Questions?



Foley Catheter Insertion

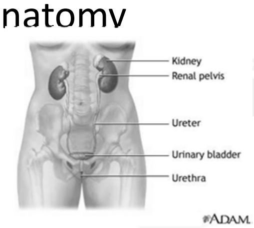
I have to put that where?

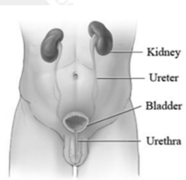
Learning Objectives

Anatomy	Be familiar with the basic anatomy of the bladder and urethra for both males and females
Indications	Understand why and when it is appropriate to use a Foley catheter
Contraindications	Understand when NOT to use a Foley
Equipment	Identify the equipment necessary to insert a Foley
Preparation	Best practices for inserting a Foley
Insertion	A step by step approach to inserting a Foley

2

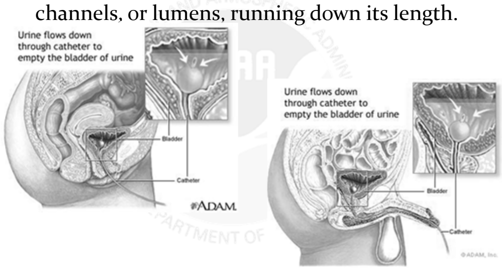
Anatomy



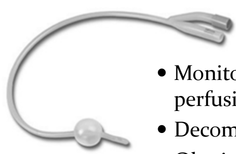


Foley Catheter

- Is a flexible tube that is passed through the urethra and into the bladder. The tube has two separated channels, or lumens, running down its length.



Indications



- Monitor volume status and renal perfusion
- Decompress the bladder
- Obtain a specimen
- Bladder outlet obstruction

Contraindications

- Foley catheters are contraindicated in the presence of urethral trauma. Urethral injuries may occur in patients with multisystem injuries and pelvic factures, as well as straddle impacts.

- If this is suspected, stop and call NOAA health services for guidance.

Equipment

- Sterile gloves - Consider Universal Precautions
- Sterile drapes
- Cleansing solution and Cotton swabs
- Forceps
- Sterile water (usually 10 cc)
- Foley catheter (usually 16-18 French)
- Syringe (usually 10 cc)
- Lubricant (water based jelly or xylocaine jelly)
- Collection bag and tubing

Preparation

- Gather equipment
- Explain procedure to the patient
- Don non sterile gloves and help patient remove clothes from the naval down.
- Assist patient into supine position with legs spread and feet together
- Open Foley kit and catheter. (Be sure not to touch anything inside until you have donned your sterile gloves)
- Prepare sterile field
- Don sterile gloves
- Test inflate the catheter by inflating it with the water in the syringe.

Preparation

- Generously coat the distal portion (2-5 cm) of the catheter with lubricant
- Open sterile betadine in kit and pour over cotton balls in the plastic carton
- Apply sterile drape
- Let your patient know that you are going to clean them before inserting the catheter
- Pick up the cotton balls one at a time and clean the meatus (urethra opening)

Preparation

- If female, separate labia using non-dominant hand. If male, hold the penis with the non-dominant hand. Maintain hand position until preparing to inflate balloon.
- Using dominant hand to betadine swabs, cleanse peri-urethral mucosa with cleansing solution. Cleanse anterior to posterior, inner to outer, one swipe per swab, discard swab away from sterile field.

Insertion

- Pick up catheter with gloved (and still sterile) dominant hand. Hold end of catheter loosely coiled in palm of dominant hand.
- In the male, lift the penis to a position perpendicular to patient's body and apply light upward traction (with non-dominant hand).
- Ask patient to take a deep breath. Identify the urinary meatus and gently insert until 1 to 2 inches beyond where urine is noted.
- If you meet resistance you might try swiveling the catheter a bit and inserting once again. As you do, be aware of patient's discomfort. Don't use undue force. The patient may have strictures or an enlarged prostate.
- Inflate balloon, using correct amount of sterile liquid (usually 10 cc but check actual balloon size).
- Gently pull catheter until inflation balloon is snug against bladder neck.
- Connect catheter to drainage system.

Secure

- Secure catheter to abdomen or thigh, without tension on tubing
- Place drainage bag below level of bladder
- Evaluate catheter function and amount, color, odor, and quality of urine
- Remove gloves, dispose of equipment appropriately, wash hands
- Make sure patient is comfortable and modestly covered once again
- Document size of catheter inserted, amount of water in balloon, patient's response to procedure, and assessment of urine

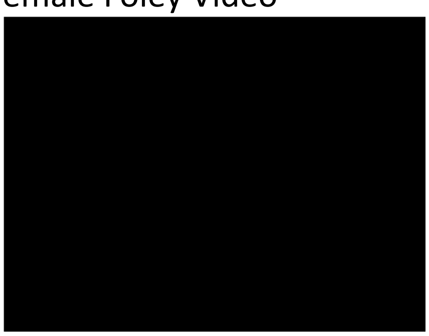
Female Helpful Hints

- With your non-dominant hand, use your thumb and place it approximately one half to one inch below the clitoris, pushing slightly in and upward at the same time. This will cause the urinary meatus to be visible, and places tension on the tissue, stabilizing it.
- In this way, the meatus does not get pushed inward or "roll" when you insert the catheter. Additionally, positioning your thumb in this way holds the labia minora in a retracted position, keeping it out of the way.
- When you are ready to insert the catheter, be sure to grasp it no more than approximately one and a half to two inches from the distal end. This will aide in keeping the insertion end stable, and prevent it from moving and being inadvertently placed into the vaginal opening.

Complications

- The main complications are **tissue trauma and infection**.
- After 48 hours of catheterization, most catheters are colonized with bacteria, thus leading to possible bacteruria.
- The most common short term complications are **inability to insert catheter**, and causation of tissue trauma during the insertion.
- In some cases, as in urethral stricture or prostatic hypertrophy, insertion will be difficult and may not be possible.

Female Foley Video



Male Foley Video

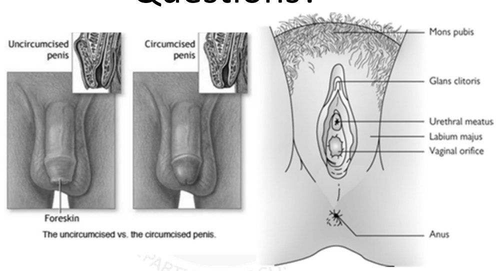
Be Professional

- If you are uncomfortable, how much more uncomfortable might your patient be ?
- Do your best to help your patient feel relaxed.

Key Points

- Know what you are getting into. Inspect your patient before you start looking for unusual anatomy, piercings, ex…
- Inspect your equipment and take your time setting up (if time allows). You will be much more relaxed if everything you need is right there.
- Be professional

Questions?


Uncircumcised penis
Circumcised penis
Foreskin
The uncircumcised vs. the circumcised penis.
Mons pubis
Glans clitoris
Urethral meatus
Labium majus
Vaginal orifice
Anus

Pulmonary Injury and Needle Decompression

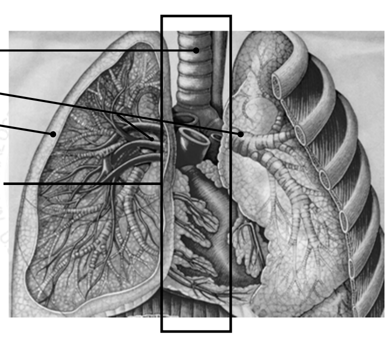
General

- Chest injuries may result from:
  - Gunshot wounds (GSW)
  - Shrapnel
  - Explosions
  - Motor vehicle crashes (MVC)
  - Falls
  - Crush injuries
  - Stab wounds
  - Pulmonary Over Inflation Injury

2

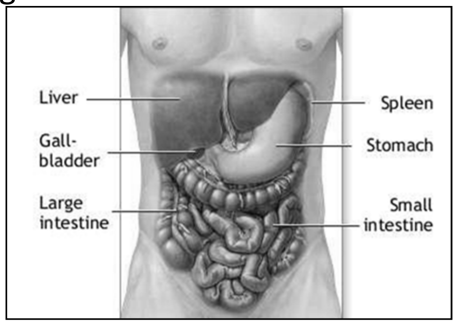
Organs of the Thorax

- Trachea
- Bronchi
- Lungs
- Mediastinum



3

Organs of the Abdomen



4

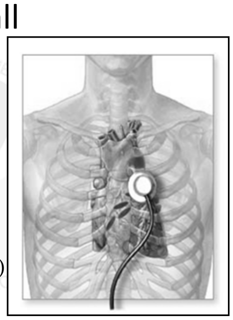
Assess Respirations

- Respiratory rate and effort:
  - Tachypnea
  - Bradypnea
  - Labored
  - Retractions
  - Progressive respiratory distress

5

Assess the Chest Wall

- Lung sounds – Percussion.
  - Absent or decreased
    - Unilateral
    - Bilateral
  - Hyperresonance
    - Pneumothorax
    - Tension pneumothorax
  - Hyporesonance (hemothorax)



6

Assess the Chest Wall

- Compare both sides of the chest at the same time when assessing for asymmetry.

7

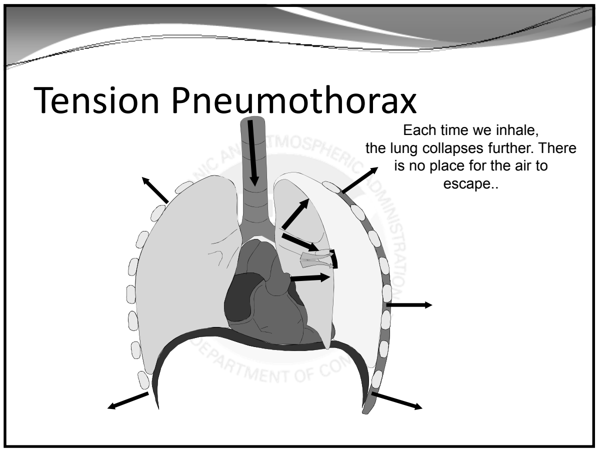
Chest Physiology

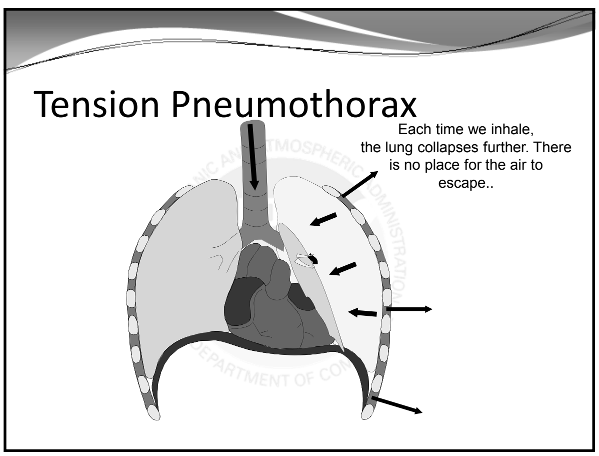
- Chest normally has negative pressure.
- Penetrating wound creates a positive pressure in chest cavity.
- Air will enter the easiest route. If a hole in the chest is smaller than 2/3 the size of the trachea, air will enter through the trachea preferentially and not through the hole in the chest.

8

Tension Pneumothorax

- Air builds in pleural space with no where for the air to escape
- Results in collapse of lung on affected side that results in pressure on mediastium,the other lung, and great vessels


Tension Pneumothorax
Each time we inhale, the lung collapses further. There is no place for the air to escape..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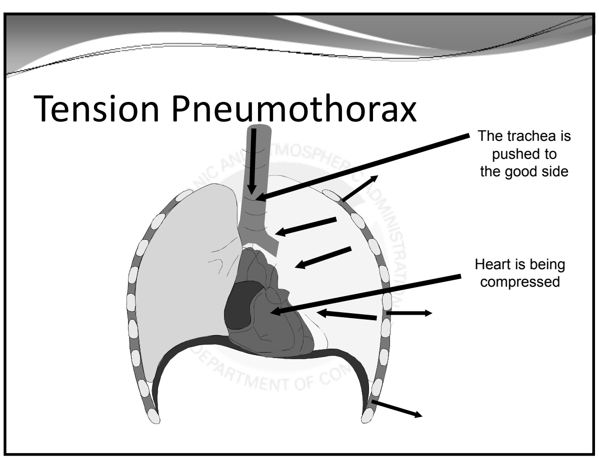
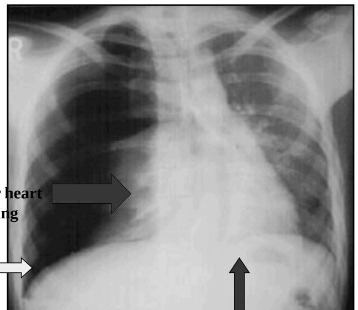

Tension Pneumothorax
The trachea is pushed to the good side
Heart is being compressed

Tension Pneumothorax



Air pushes over heart and collapses lung

Air outside lung from wound

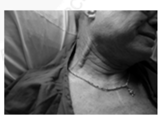
Heart compressed not able to pump well

13

Signs and Symptoms of Tension Pneumothorax

- Anxiety, agitation, and apprehension
- Diminished or absent breath sounds
- Cyanosis

- Rapid shallow breathing (tachypnea)
- Distended neck veins



Signs and Symptoms of Tension Pneumothorax

- Clinical presentation:
  - Diminished or absent breath sounds
  - Hyperresonance to percussion on affected side
  - Hypotension, cold clammy skin
  - Casualty begins to deteriorate rapidly
  - Decreased lung compliance (intubated)
  - Tracheal deviation (*late*)

15

Tension Pneumothorax

- If after sealing the open pneumothorax, the casualty develops progressive difficulty breathing, consider this a tension pneumothorax and perform a needle chest decompression.
- If no capability of NCD exists and the casualty continues to have progressive respiratory distress, remove the occlusive dressing and stick a gloved finger into the open wound and attempt to "burp" the wound.

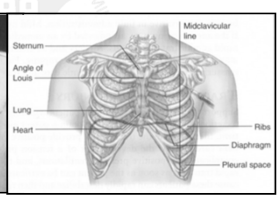
16

Needle Decompression

- Locate 2-3 Intercostal space midclavicular line
- Cleanse area using aseptic technique
- Insert catheter (14g or larger) at least 3" in length over the top of the 3rd rib(nerve, artery, vein lie along bottom of rib)
- Remove Stylette and listen for rush of air
- Place Flutter valve over catheter
- Reassess for Improvement

Needle Chest Decompression

- Procedure:
  - Identify the second ICS on the anterior chest wall, MCL:



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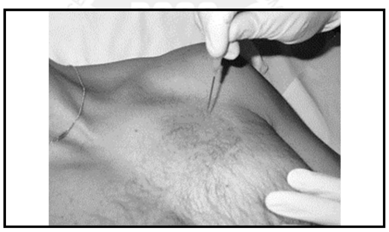
Needle Chest Decompression

- Prep the area with an antimicrobial agent.
- Insert a 14 ga. Catheter at 90° angle over the top of 3rd rib, into the 2nd ICS the MCL.
- Needle should be long to enter the chest (3 inches).

19

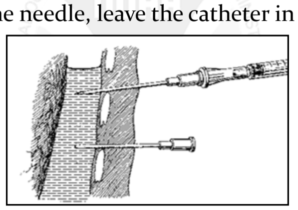
Performing a Needle Chest Decompression

Firmly insert the needle into the skin at a 90 degree angle relative to the curvature of the skin.



Needle Chest Decompression

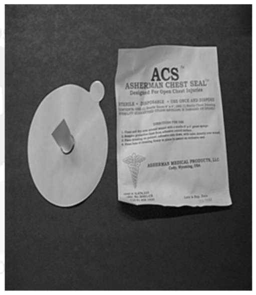
- If a tension pneumothorax is present, a "hiss of air" may be heard escaping from the chest cavity.
- Remove the needle, leave the catheter in place.



21

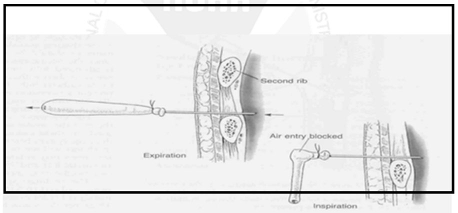
Flutter Valve

- Asherman Chest Seal makes good Flutter Valve .



Flutter Valve

May also use a finger from a latex glove.



Tension Pneumothorax

- Management:
  - Ensure an open airway
  - Decompress the affected side
- Indications:
  - Penetrating chest wound with progressive respiratory distress

24

Needle Chest Decompression

- Tape the catheter hub to the chest wall.
- The casualty's condition should rapidly improve.
- Evacuate ASAP.

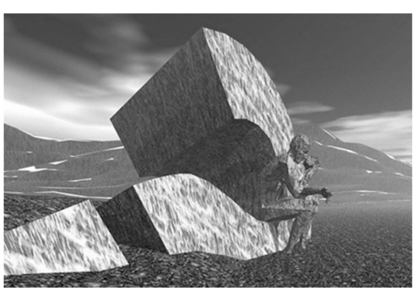
25

Needle Chest Decompression

- Complications:
  - Insertion of the needle over the top of the rib prevents laceration of the intercostal vessels or nerve which can cause hemorrhage or nerve damage.

26

Questions?



US Navy Decompression Tables and Procedures

1

Global View

- Definition of decompression
- Explanation of USN Air Decompression Table
- Table usage
- Decompression options

Decompression Dives

- Technically, decompression is something that happens on every dive
- For the purposes of this presentation decompression diving means that the diver has exceeded the no-decompression limits and therefore, cannot ascend directly back to the surface without stopping at specific depths for specific dives, called "decompression stops"
- NOAA utilizes the US Navy Air Decompression Tables (Table 9-9) for air dives that exceed the no-decompression limits

USN Air Decompression Table (9-9)

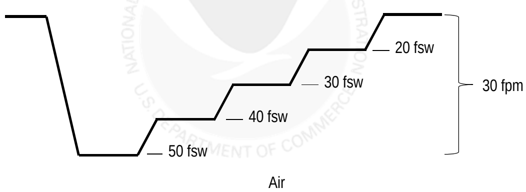
- Depth
- Time to first stop
- Gas mixture
- Decompression stops
- Total ascent time
- Chamber O2 periods
- Repetitive group letter

Table 9-9. *Air Decompression Table (Continued).*
(DESCENT RATE 75 FPM—ASCENT RATE 30 FPM)

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop 100	90	80	70	60	50	40	30	20	Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
60 FSW														
60	2:00	AIR									0	2:00	0	K
		AIR/O_2									**0**	2:00		
65	1:20	AIR									2	4:00	0.5	L
		AIR/O_2									**1**	3:00		
70	1:20	AIR									7	9:00	0.5	L
		AIR/O_2									**4**	6:00		
80	1:20	AIR									14	16:00	0.5	N
		AIR/O_2									**7**	9:00		
In-Water Air/O_2 Decompression or SurDO_2 Recommended														
90	1:20	AIR									23	25:00	0.5	O
		AIR/O_2									**10**	12:00		
100	1:20	AIR									42	44:00	1	Z
		AIR/O_2									**15**	17:00		
110	1:20	AIR									57	59:00	1	Z
		AIR/O_2									**21**	23:00		
120	1:20	AIR									75	77:00	1	Z
		AIR/O_2									**26**	28:00		
Exceptional Exposure: In-Water Air Decompression — In-Water Air/O_2 Decompression or SurDO_2 Required														
130	1:20	AIR									102	104:00	1.5	Z
		AIR/O_2									**31**	33:00		
140	1:20	AIR									124	126:00	1.5	Z
		AIR/O_2									**35**	37:00		
150	1:20	AIR									143	145:00	2	Z
		AIR/O_2									**41**	48:00		
160	1:20	AIR									158	160:00	2	Z
		AIR/O_2									**48**	55:00		
170	1:20	AIR									178	180:00	2	
		AIR/O_2									**53**	60:00		
180	1:20	AIR									201	203:00	2.5	
		AIR/O_2									**59**	66:00		
190	1:20	AIR									222	224:00	2.5	
		AIR/O_2									**64**	71:00		
200	1:20	AIR									240	242:00	2.5	
		AIR/O_2									**68**	80:00		
210	1:20	AIR									256	258:00	3	
		AIR/O_2									**73**	85:00		
220	1:20	AIR									278	280:00	3	
		AIR/O_2									**77**	89:00		
Exceptional Exposure: In-Water Air/O_2 Decompression — SurDO_2 Required														
230	1:20	AIR									300	302:00	3.5	
		AIR/O_2									**82**	94:00		
240	1:20	AIR									321	323:00	3.5	
		AIR/O_2									**88**	100:00		
270	1:20	AIR									398	400:00	4	
		AIR/O_2									**102**	119:00		
Exceptional Exposure: SurDO_2														
300	1:20	AIR									456	458:00	4.5	
		AIR/O_2									**115**	132:00		

Decompression Options

- In-water decompression on Air
  - This mode of decompression is used when all decompression will be conducted on Air



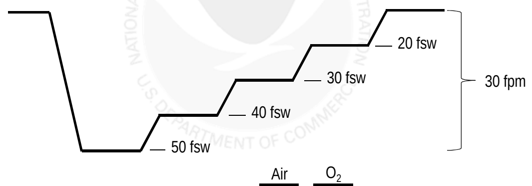
Decompression Options

- In-water decompression on Air
  - Use the entire top row on the Table marked Air
  - Last decompression stop is 20 fsw, there are no 10' stops
  - 30 fpm ascent

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop 100	90	80	70	60	50	40	30	20	Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
60 FSW														
60	2:00	AIR									0	2:00	0	K
		AIR/O_2									**0**	2:00		
65	1:20	AIR									2	4:00	0.5	L
		AIR/O_2									**1**	3:00		
70	1:20	AIR									7	9:00	0.5	L
		AIR/O_2									**4**	6:00		
80	1:20	AIR									14	16:00	0.5	N
		AIR/O_2									**7**	9:00		

Decompression Options (Cont)

- In-water decompression using Air and Oxygen
  - This mode of decompression is used when the decompression will be conducted partly on air and partly on 100% oxygen



Decompression Options (Cont)

- In-water decompression using Air and 100% Oxygen
  - Use the "Air/O2" row to get stop times - O2 times are printed in **bold** numbers)
  - Follow the air schedule to 30 fsw and shift divers to 100% oxygen at 30 fsw (or 20 fsw if not a 30 fsw stop)

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop 100	90	80	70	60	50	40	30	20	Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
60 FSW														
60	2:00	AIR									0	2:00	0	K
		AIR/O_2									**0**	2:00		
65	1:20	AIR									2	4:00	0.5	L
		AIR/O_2									**1**	3:00		
70	1:20	AIR									7	9:00	0.5	L
		AIR/O_2									**4**	6:00		
80	1:20	AIR									14	16:00	0.5	N
		AIR/O_2									**7**	9:00		

Decompression Options (Cont)

- In-water decompression using Air and 100% Oxygen (Cont)
  - Oxygen stop time starts when all divers are confirmed on Oxygen

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop 100	90	80	70	60	50	40	30	20	Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
60 FSW														
60	2:00	AIR									0	2:00	0	K
		AIR/O_2									**0**	2:00		
65	1:20	AIR									2	4:00	0.5	L
		AIR/O_2									**1**	3:00		
70	1:20	AIR									7	9:00	0.5	L
		AIR/O_2									**4**	6:00		
80	1:20	AIR									14	16:00	0.5	N
		AIR/O_2									**7**	9:00		

Decompression Options (Cont)

- In-water decompression using Air and 100% Oxygen (Cont)
  - 5 minute air breaks must be taken for every :30 spent on oxygen. If the final O2 period is :35 or less, disregard the last :05 air break.

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop									Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
			100	90	80	70	60	50	40	30	20			
60 FSW														
60	2:00	AIR									0	2:00	0	K
		AIR/O_2									0	2:00		
65	1:20	AIR									2	4:00	0.5	L
		AIR/O_2									1	3:00		
70	1:20	AIR									7	9:00	0.5	L
		AIR/O_2									4	6:00		
80	1:20	AIR									14	16:00	0.5	N
		AIR/O_2									7	9:00		

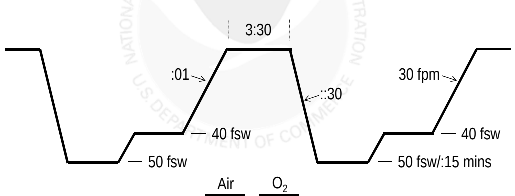
Decompression Options (Cont)

- In-water decompression using Air and 100% Oxygen (Cont)
  - Upon completion of the 20 fsw O2 stop, the diver is brought surface at 30 fsw/min breathing oxygen.

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop									Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
			100	90	80	70	60	50	40	30	20			
60 FSW														
60	2:00	AIR									0	2:00	0	K
		AIR/O_2									0	2:00		
65	1:20	AIR									2	4:00	0.5	L
		AIR/O_2									1	3:00		
70	1:20	AIR									7	9:00	0.5	L
		AIR/O_2									4	6:00		
80	1:20	AIR									14	16:00	0.5	N
		AIR/O_2									7	9:00		

Decompression Options (Cont)

- Surface decompression on 100% Oxygen
  - A technique for fulfilling all or a portion of a diver's decompression obligation in a recompression chamber instead of in the water.



Decompression Options (Cont)

- Surface decompression on 100% Oxygen
  - Complete 40 fsw and deeper stops
  - Bring diver to surface in one (1) minute (40 fpm)
  - Undress diver and begin recompression within 3:30

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop 100	90	80	70	60	50	40	30	20	Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
170 FSW														
5	5:40	AIR									0	5:40	0	D
		AIR/O_2									0	5:40		
10	5:00	AIR									2	7:40	0.5	G
		AIR/O_2									1	6:40		
15	5:00	AIR									7	12:40	0.5	J
		AIR/O_2									4	9:40		
In-Water Air/O_2 Decompression or SurDO_2 Recommended														
20	4:40	AIR								1	29	35:20	1	L
		AIR/O_2								1	15	21:20		
25	4:20	AIR							1	6	46	58:00	1	N
		AIR/O_2							1	4	23	33:20		
Exceptional Exposure: In-Water Air Decompression —— In-Water Air/O_2 Decompression or SurDO_2 Required														
30	4:20	AIR							5	11	72	93:00	1.5	Z
		AIR/O_2							5	6	29	45:20		
35	4:00	AIR						2	9	17	113	145:40	2	Z
		AIR/O_2						2	9	9	35	65:00		
40	4:00	AIR						6	13	23	155	201:40	2.5	Z
		AIR/O_2						6	13	12	43	84:00		
Exceptional Exposure: In-Water Air/O_2 Decompression —— SurDO_2 Required														
45	4:00	AIR						12	16	28	194	254:40	2.5	
		AIR/O_2						12	16	15	54	109:00		

Decompression Options (Cont)

- Surface decompression on 100% Oxygen (Cont)
  - Compress diver to 50 fsw @ 100 fpm on air
  - At 50 fsw, place diver on 100% oxygen for 15 minutes
  - Ascend to 40 fsw @30 fpm

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop 100	90	80	70	60	50	40	30	20	Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
170 FSW														
5	5:40	AIR									0	5:40	0	D
		AIR/O_2									0	5:40		
10	5:00	AIR									2	7:40	0.5	G
		AIR/O_2									1	6:40		
15	5:00	AIR									7	12:40	0.5	J
		AIR/O_2									4	9:40		
In-Water Air/O_2 Decompression or SurDO_2 Recommended														
20	4:40	AIR								1	29	35:20	1	L
		AIR/O_2								1	15	21:20		
25	4:20	AIR							1	6	46	58:00	1	N
		AIR/O_2							1	4	23	33:20		
Exceptional Exposure: In-Water Air Decompression —— In-Water Air/O_2 Decompression or SurDO_2 Required														
30	4:20	AIR							5	11	72	93:00	1.5	Z
		AIR/O_2							5	6	29	45:20		
35	4:00	AIR						2	9	17	113	145:40	2	Z
		AIR/O_2						2	9	9	35	65:00		
40	4:00	AIR						6	13	23	155	201:40	2.5	Z
		AIR/O_2						6	13	12	43	84:00		
Exceptional Exposure: In-Water Air/O_2 Decompression —— SurDO_2 Required														
45	4:00	AIR						12	16	28	194	254:40	2.5	
		AIR/O_2						12	16	15	54	109:00		

Decompression Options (Cont)

- Surface decompression on 100% Oxygen (Cont)
  - Breath O2 for 15 minutes then take 5 minute air break
  - Continue breathing O2/Air in 30/5 minute periods
  - If more than four (4) O2 periods, complete additional ones @ 30 fsw

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop 100	90	80	70	60	50	40	30	20	Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
170 FSW														
5	5:40	AIR									0	5:40	0	D
		AIR/O_2									0	5:40		
10	5:00	AIR									2	7:40	0.5	G
		AIR/O_2									1	6:40		
15	5:00	AIR									7	12:40	0.5	J
		AIR/O_2									4	9:40		
In-Water Air/O_2 Decompression or SurDO_2 Recommended														
20	4:40	AIR								1	29	35:20	1	L
		AIR/O_2								1	15	21:20		
25	4:20	AIR							1	6	46	58:00	1	N
		AIR/O_2							1	4	23	33:20		
Exceptional Exposure: In-Water Air Decompression —— In-Water Air/O_2 Decompression or SurDO_2 Required														
30	4:20	AIR							5	11	72	93:00	1.5	Z
		AIR/O_2							5	6	29	45:20		
35	4:00	AIR						2	9	17	113	145:40	2	Z
		AIR/O_2						2	9	9	35	65:00		
40	4:00	AIR						6	13	23	155	201:40	2.5	Z
		AIR/O_2						6	13	12	43	84:00		
Exceptional Exposure: In-Water Air/O_2 Decompression —— SurDO_2 Required														
45	4:00	AIR						12	16	28	194	254:40	2.5	
		AIR/O_2						12	16	15	54	109:00		

Decompression Options (Cont)

- Surface decompression on 100% Oxygen (Cont)
  - Upon completion, bring diver to surface @30 fpm breathing air
  - If no RGD provided, diver must wait 18 hours before making another dive

Bottom Time (min)	Time to First Stop (M:S)	Gas Mix	DECOMPRESSION STOPS (FSW) Stop times (min) include travel time, except first air and first O_2 stop 100	90	80	70	60	50	40	30	20	Total Ascent Time (M:S)	Chamber O_2 Periods	Repet Group
170 FSW														
5	5:40	AIR									0	5:40	0	D
		AIR/O_2									0	5:40		
10	5:00	AIR									2	7:40	0.5	G
		AIR/O_2									1	6:40		
15	5:00	AIR									7	12:40	0.5	J
		AIR/O_2									4	9:40		
In-Water Air/O_2 Decompression or SurDO_2 Recommended														
20	4:40	AIR								1	29	35:20	1	L
		AIR/O_2								1	15	21:20		
25	4:20	AIR							1	6	46	58:00	1	N
		AIR/O_2							1	4	23	33:20		
Exceptional Exposure: In-Water Air Decompression —— In-Water Air/O_2 Decompression or SurDO_2 Required														
30	4:20	AIR							5	11	72	93:00	1.5	Z
		AIR/O_2							5	6	29	45:20		
35	4:00	AIR						2	9	17	113	145:40	2	Z
		AIR/O_2						2	9	9	35	65:00		
40	4:00	AIR						6	13	23	155	201:40	2.5	Z
		AIR/O_2						6	13	12	43	84:00		
Exceptional Exposure: In-Water Air/O_2 Decompression —— SurDO_2 Required														
45	4:00	AIR						12	16	28	194	254:40	2.5	
		AIR/O_2						12	16	15	51	109:00		

Deco Mode Selection Flowchart

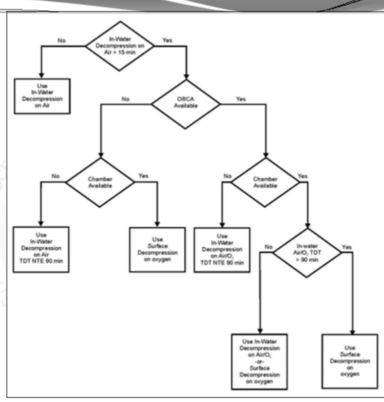


Table Question

- Scenario #1: A DMO is locked into a recompression chamber and pressurized to 60 fsw to check on a patient. The DMO has a bottom time of 55 minutes. Three (3) hours later, the DMO is again locked into the chamber and pressurized to 60 fsw and has a bottom time of 45 minutes.
- Question #1: Is a decompression stop required? If so, at what depth and for how long?

Table Question (Cont)

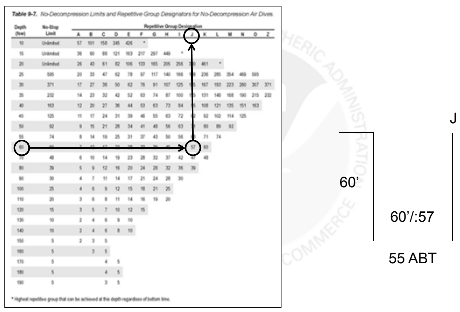


Table Question (Cont)

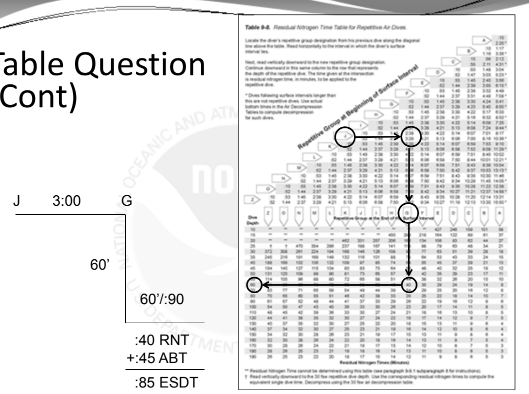


Table Question (Cont)

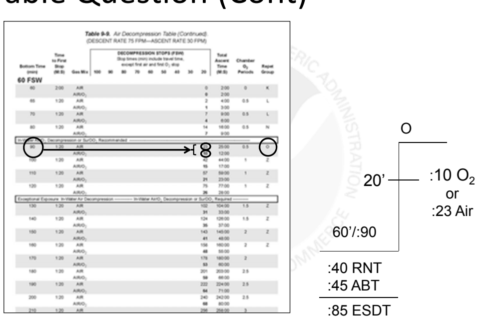


Table Question (Cont)

- Here's how the dive would be diagrammed

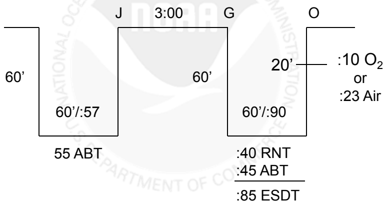
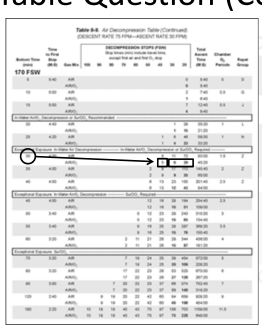
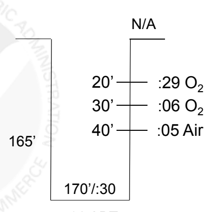


Table Question

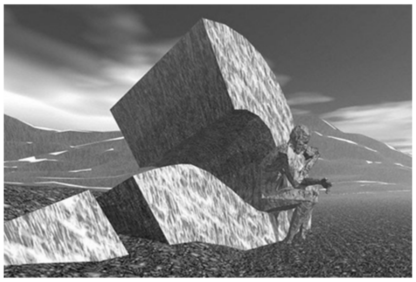
- Scenario #2: A DMO is locked into a recompression chamber with a patient and both are pressurized to 165 fsw. After 30 minutes, the DMO is locked into the outer lock and decompressed to the surface.
- Question #2: Is a decompression stop required? If so, at what depth and for how long?

Table Question (Cont)





Questions?



Pathophysiology of Decompression

and

Acute Dysbaric Disorders

Acknowledgments

Dr. Klaus Torp, MD
Mayo Clinic College of Medicine

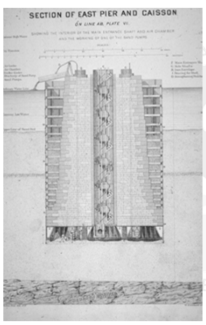
Overview

- History
- Definition of Decompression Illness
- Diagnosis of Decompression Illness
- Treatment of Decompression Illness
- Complications of HBO treatment
- Case Histories

Nomenclature

- AGE = Arterial gas embolism
  - CAGE=Cerebral arterial gas embolism
- DCS = Decompression sickness
  - Type 1=Bends pain, mild skin symptoms 1960
  - Type 2=Neurological symptoms Golding 1960 *(Caisson)*
  - Type 3=AGE and Type 2 DCS Neuman, Bove 1990
- DCI = Decompression Illness UHMS WS 1989
- Signs and Symptoms after diving
  - i.e. loss of balance after diving Ross Aberdeen 2003

St. Louis Bridge, 1870



119 cases of bends recorded: 2 crippled for life, 14 deaths.

Bends in a Caisson Worker

"...it would appear that...the man brought his fate upon himself. He had failed to bring his dinner, so went home to eat it, contrary to orders. Then, on the way back, he 'filled himself' with beer. Moreover, on coming up from his second watch, he left the works before his hour of rest was up. On reaching home in the afternoon, the man was taken sick with vomiting. In a few minutes general paralysis supervened."

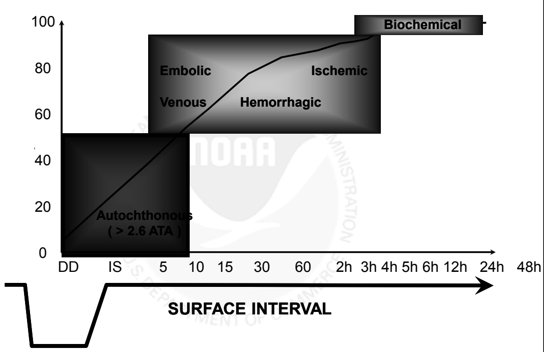
Woodward, 1881

Pathophysiology

- Inert gas (Nitrogen, Helium)
- Stored in tissues
- Slow elimination by the lungs on ascent
  - Tissue half-times
- Bubble formation on ascent
  - In tissues
  - In venous system
  - In arterial system

Decompression Illness

Latency vs. Mechanism



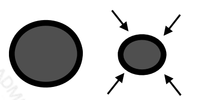
Modified from: Francis et al. *UBR* 15: 403-417, 1988.

Bubble Trouble

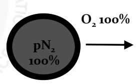
- **Decompression Sickness (DCS)**
  - **SCUBA divers, pilots, and astronauts**
  - **Staff in multiplace chambers**
- **Arterial Gas Embolism (AGE)**
  - **SCUBA divers: breath holding upon ascent**
  - **Iatrogenic: with some medical procedures**

HBO_2 Effect on Gas Bubbles

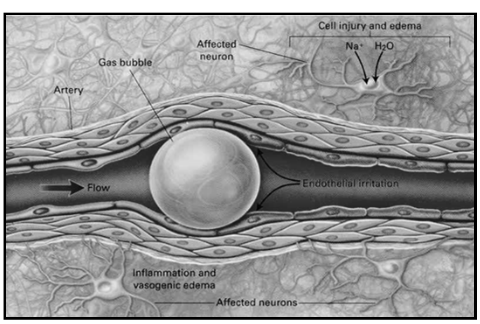
- **Pressure**
  - **Shrink bubbles (Boyle's Law)**
- **Gas Gradient**
  - **Diffuse inert gas out of bubbles**



Effective Intervention for:
- **Arterial gas embolism**
- **Decompression illness**



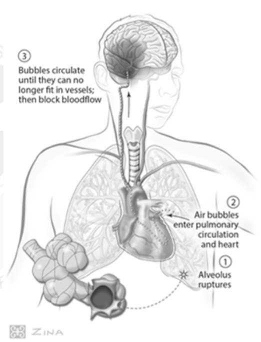
Bubble Trouble



Muth CM. N Engl J Med 2000

Arterial Gas Embolism

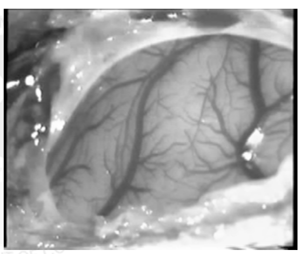
- Part of DCI
- Lung over-inflation
- Large or small
- Wide symptom range
  - Unconsciousness
  - Bloody frothy sputum
  - Mild bends pain



Cerebral Arterial Gas Embolism

- Destruction of endothelial layer
- Bubbles on the venous side can send inflammatory cytokines (MP ?) to the arterial side
- Leucocyte adhesion
  - Activation by MP ?

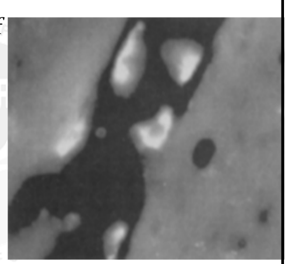
Thom UHM 2011



Helps SC, Gorman DF. Stroke 22:351 1991

Leukocyte Adhesion in DCS/AGE

- Progressive obstruction of blood flow
- Absent in leukocyte depleted animals
- Inhibited by HBO & $ß_2$ Integrin antibodies
  - New human AB developed Eli Lilly



Martin JD, Thom SR. Aviat Space Environ Med 73:565 2002

Helps SC, Gorman DF. Stroke 22:351 1991

Who gets DCI ?

- Anybody
- Any dive profile at any depth can cause signs or symptoms after diving that may respond to recompression USN Dive Manual Rev 6
- Without mistakes (this leads to denial)
- It is a diving disease waiting to happen
- The only 2 ways not to get bent is
  - Never go in the water
  - Never come up

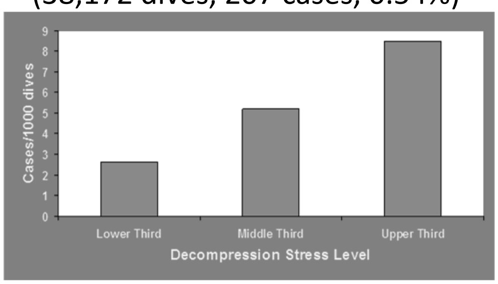
Incidence

- True incidence not known
  - Prevalence 1000 cases/year in US divers
- Difficult to obtain due to unknown number of dives
  - Reluctance of dive operators to report dives
  - Reluctance of diver to report DCI
  - Subsistence fishermen / pearl divers
- Small samples
  - Live-aboard, few dive centers
- Only few studies and data exist
  - Different dives, temperature etc difficult to compare

Existing incidence data

- "Warm Water" dives PDE DAN data
  - DCS incidence: 2 cases per 10,000 dives
- "Cold Water" dives PDE DAN data
  - DCS incidence: 28 cases/10,000 dives
- U.S. Navy Dive Trials Data
  - DCS incidence: 311 cases per 10,000 dives

DCS Incidence with Standard Air Table 1971-96 (38,172 dives, 207 cases, 0.54%)

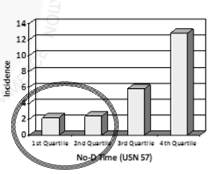


NAVSEA Flynn 2009

Risk of DCS in no-D limits US Navy diving

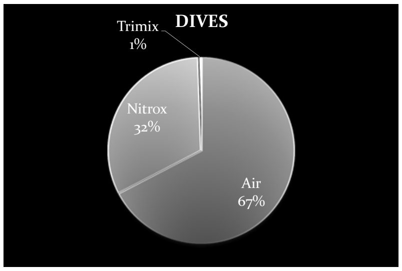
- **Naval Safety Center, 1990-1994**
- **163,400 no-decompression dives, 21-55 fsw**
- **48 DCS cases (all no-D time limit)**
- **Overall DCS incidence: 2.9 per 10,000 dives**

One can have clinical DCI with less than ½ of exposure time (M values)



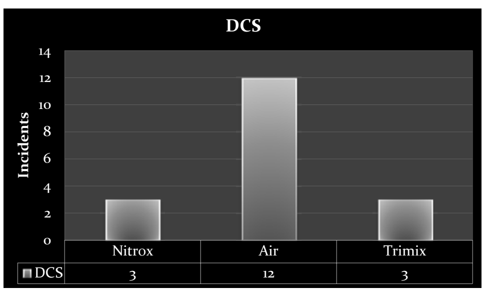
Flynn ET, Parker EC, Ball R., NMRI 1998

NOAA Diving 2001 - 2011



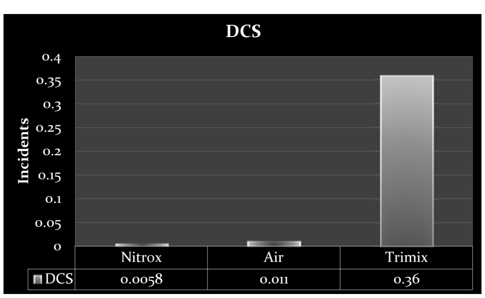
2001-2011 NOAA data

NOAA Diving 2001 - 2011



2001-2011 NOAA data

NOAA Diving 2001 - 2011



2001-2011 NOAA data

Is it safe to dive?

Safety: "Freedom from Injury"

- Oxford Dictionary

- Most activities are not injury-free
- Safety is determined by <u>risk of injury</u>
- Risk depends on <u>probability</u> & <u>severity</u>
  - Curable injury is more acceptable than permanent injury
- So acceptable risk is <u>subjective</u>
  - For an individual, it's <u>personal</u>
  - For an organization, it's <u>political</u>

Risk factors

- Multiple dives per day ?
- Multiple diving days ?
- Multiple ascents
- Decompression dives
- Diving tables to the limits (USN 2-3%)

Risk factors

- Dehydration — Fahlman et al. ASEM Feb 2006
  - Alcohol
- Fatigue
- Gender ? — Lee et al; ASEM Nov 2003
  - PFO ? — Mutzbauer et al; UHM 2005
- Age
  - Prone to more and more severe DCI

Freiberger et al. UHMS ASM June 2006
Conkin et al. ASEM 2003 (altitude)

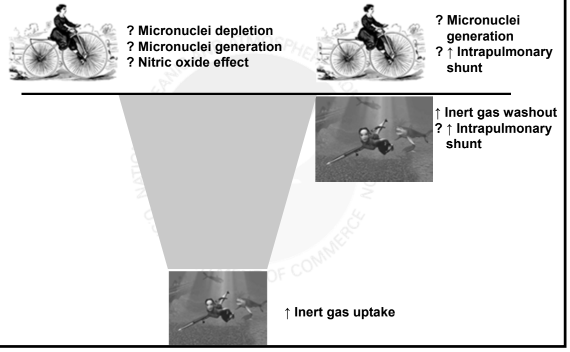
Multivariate Model for DCS

1250 DCS cases / 3800 non DCS cases — Denoble et al. UHMS ASM 2005

Variable	OR	LCL	UCL	p-value
Depth of last dive (per 50 fsw)	↑ **2.26**	2.01	2.53	<0.0001
Previous DCI	↑ **1.99**	1.35	2.94	0.0005
Days diving (per 5 days)	↑ **1.53**	1.14	2.06	0.005
Male	↑ **1.19**	1.01	1.40	0.044
Dives in past year (per 10 dives)	↓ **0.95**	0.94	0.96	<0.0001
Age (per 10 years)	↓ **0.92**	0.86	0.99	0.0247
Years diving (per 10 years)	↓ **0.89**	0.80	0.98	0.0145
Drysuit	↓ **0.72**	0.59	0.89	0.0018
Number of dives (per 5 dives)	↓ **0.56**	0.50	0.64	<0.0001
Nitrox	↓ **0.48**	0.39	0.61	<0.0001

↑ *OR >1 = risk factor* ↓ *OR <1 = protective factor*

Effect of Exercise on DCS Risk



Micronuclei

- Gas bubbles grow from pre-existing gas nuclei (~<1μm)
  - Need high super-saturation pressure for de-novo bubble formation
- Gas bubbles can exist in crevices on hydrophobic endothelial cells
- Exercise can produce "cavitations", producing bubbles (tribonucleation)
- ? Tissue trauma effect on micro-nuclei

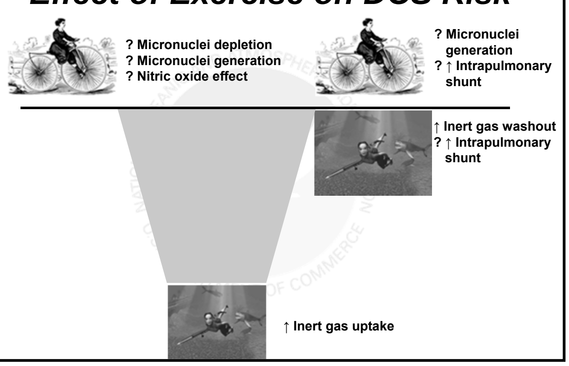
Exercise before diving

- Vigorous exercise 24 hrs before the dive reduced bubble load (in man) however not at 12 hrs or 48 hrs or 30 min (in rats)

  Dujik et al. J Physiol 2004, Berge et al. ASEM 2005; 76:326–8.
- Exercise 2 hr pre dive reduces VGE in man

  Blatteau et al. ASEM 2005
- Timing?
- Intensity?
- Mechanism?

Effect of Exercise on DCS Risk



Exercise on the bottom

- Increase CO_2 production
- Increase perfusion
- Increase ventilation
- Need longer off-gassing time
- In high PO_2 environment may decrease seizure threshold

Exercise Effect During <u>Bottom time</u> on VGE in Wet Dives

RESEARCH ARTICLE

Exercise Effects During Diving and Decompression on Postdive Venous Gas Emboli

Louis W. Jankowski, Peter Tikuisis, and Ronald Y. Nishi

- **Moderate intermittent exercise <u>on the bottom</u>: no effect on VGE**

Jankowksi et al. Aviat. Space Environ Med 2004

Exercise Effect <u>During Decompression</u> on VGE in Wet Dives

RESEARCH ARTICLE

Exercise Effects During Diving and Decompression on Postdive Venous Gas Emboli

Louis W. Jankowski, Peter Tikuisis, and Ronald Y. Nishi

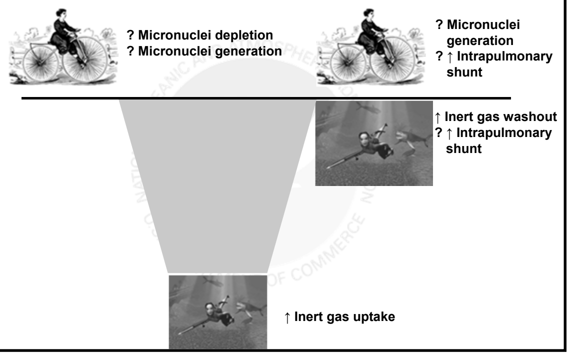
Moderate intermittent exercise: reduced VGE

Mild continuous exercise: reduced VGE

Jankowksi et al. Aviat. Space Environ Med 2004

Dujic et al. Med, Sci Sports Exerc. 2005

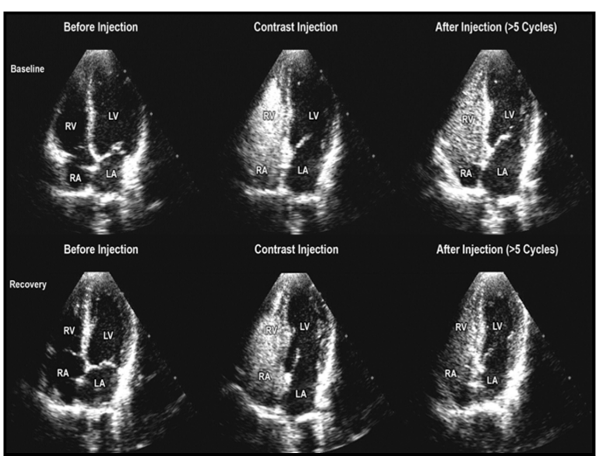
Effect of Exercise on DCS Risk

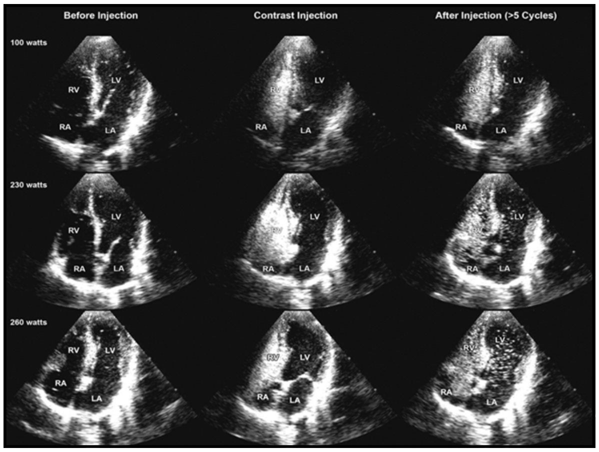


Exercise after diving

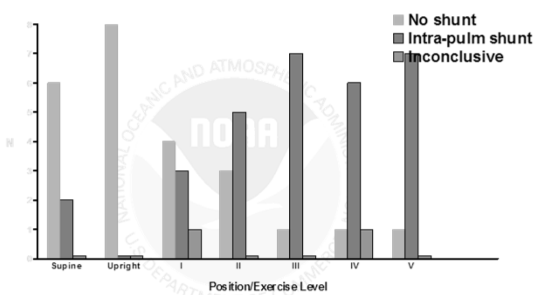
- Risk factor for DCI
  - Strenuous exercise
- May help off-gassing
  - Mild exercise
- Tough to avoid in dive instructors/masters
  - Need to stay fit
- Bouts of exercise can liberate bubbles
- Exercise can open intra-pulmonary shunts
  - 21/23 healthy volunteers on cycle ergometer

Eldridge JAP 97,2004





Transpulmonary Shunt during Exercise



Stickland MK, et al *J Physiol* 561:321, 2004

Exercise after diving

- One study failed to show right to left shunt after diving followed by exercise (85% max VO_2)
  - Bubble score was quite a bit lower than the previous contrast studies (10/11 divers)
  - 1 diver had no bubbles

Dujic et al. J Appl Physiol 2005

Symptoms of DCI

- Paresthesias
  - most common symptoms in recreational divers
  - can be intermittent and migrating
  - 67% of 200 consecutive divers

    Newton, Padilla; UHM 34(5); 2007

Symptoms of DCI

- Dull aching limb pain
  - Mostly in joints, without change during movement
  - May respond to BP cuff around the joint
- Often upper extremities in bounce diving
- Often lower extremities in saturation diving

Symptoms of DCI

- Skin symptoms
  - rash, peau d'orange, itching, tenderness
  - 16-24% out of 8424 cases
  - 21% -> 50% had neurologic symptoms

  Bird, N; UHMS ASM 2010 ;
  Newton, Padilla; UHM 34(5); 2007
- Lymphedema
  - Often on the trunk

Symptoms of DCI

- Headache
- Extreme fatigue
- Nausea / Vomiting
- Abdominal cramps
- Personality change/Mental aberration 44.5%

Cianci, Slade ASEM 2006

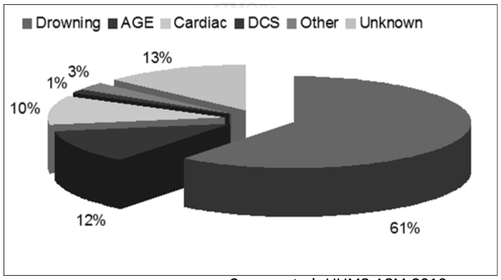
Healthy going into the Water
Sick coming out
No other explanation
Think of DCI !!

Symptoms of DCI

- Blurry vision
- Hearing problems
- Balance disturbance ("Staggers")
  - Inner ear or cerebellar symptoms
- Muscle weakness
- Breathing problems ("Chokes")
  - May also be immersion pulmonary edema
- Paralysis
- Coma

Symptoms of DCI

- Death (85 – 90 cases/year in US divers)



Caruso et al, UHMS ASM 2010

Diagnosis

- Dive History
  - Important details of dive profile ?
  - Onset of symptoms (most within 12-24 hrs)
    - Time, relation to the dive
    - Treatment and evolution of symptoms
  - Interview spouse or buddy
- General Medical history
  - Medications
    - Anti-malaria medications (i.e. Mefloquin)
      - Not a Contraindication to diving

Drugs and Diving

- Survey 442 British divers age 16-59
  - 65% male, 35% female
- 21% Prescription drugs
- 60% OTC drugs 4-6 hrs before diving
- 22% Recreational drugs since certification
- 20 divers used schedule 1 or 2 drugs within 5 min to 24 hrs prior to diving
  - Cannabis, cocaine, ecstasy 5 min - 6 hrs pre-dive

St. Leger-Dowse et al. DDRC, Plymouth UHMS 2009

Diagnosis

- History
- Physical examination
  - Look at the entire body
- Detailed neurological examination
  - Findings may not be apparent to the diver

    UHMS ASM 2006
  - Positive findings can be followed
  - No positive findings leaves only subjective symptoms to follow

General Examination

- Vital signs
- Head & Neck
  - Tympanic membranes
- Chest
  - Thorax expansion, auscultation, tracheal deviation
- Heart
- Abdomen
  - Soft, tender, normal peristalsis
- Skin
  - Warm, dry, rash, erythema

Neurologic Examination

- Mental status
- Coordination
- Cranial nerves
- Skin Sensation
- Strength
- Reflexes

Lab Tests

- Hematocrit (keep < 48%)
  >48% persistent neuro sequellae @ 1 month
  Boussuges et al. Int. J. of Sports Med 1999
  >48% correlated with severe neuro symptoms in females
  Newton, Padilla et al; UHMS 35, 2008
- Glucose (especially in unconscious patient)
- EKG if clinical suspicion
- Chest X-Ray
  - If suspicion of pneumothorax
  - Best test for pneumothorax/mediastinum is CT

Treatment Tables

- Derived by educated guess
- **Field tested !!!!** and fine tuned
- Developed by USN, RN, COMEX etc.
  - For their divers !!!
  - Failure rates may be higher in other populations

Lee JHM 6(1), 1991

- Provide pressure / time / gas profile
- They treat the patient's illness
- Provide tender decompression algorithm

Air Treatment Tables

- Air as chamber gas and breathing gas
- Take long time
- High failure rate
  - (up to 47% in recreational divers USN TT4)
  - Only 6% when originally used for USN divers

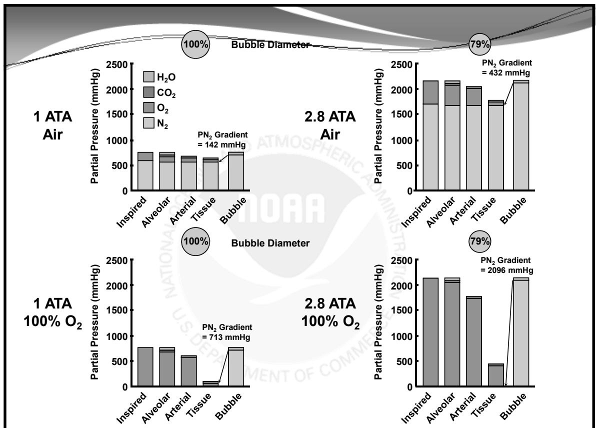
Cianci, Slade ASEM 2006

- Used for saturation treatments

Oxygen Treatment Tables

Most widely used

- Low relapse rate, good track record
- O_2 as breathing gas or chamber gas (mono)
- No on-gassing of inert gas
- HBO inhibits white cell adhesion
  - Hyperbaric air or normobaric O_2 does not
  - For life of leucocyte (24 hrs) ⇒ serial treatments
- Oxygen toxicity risk ⇒ air breaks
- Provides large inert gas gradient



Mixed Gas Treatment Tables

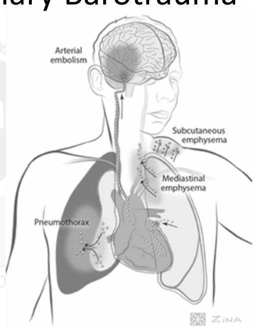
- Used for "deeper" treatments to dilute O_2
- Use Heliox or Nitrox as breathing and/or chamber gas in various mixtures
- Incurs an inert gas load
- Complex dynamics and kinetics
  - Counter diffusion superficial or deep
- Gas switching may have benefits ?
- ex: COMEX 30 (with it's many variables)

Recompression Treatment

- How late after onset of symptoms do we treat ?
  - Nobody really knows
  - Clinical response to treatment days after onset of symptoms   Vann, Lancet 337, 2011
  - Up to 2 weeks out, significant improvement
  - Longer intervals ??
  - Short Rx delay more important in mild DCI Severe cases should get transferred to best facility
    Ross UHMS ASM 2007

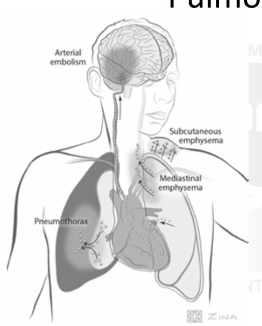
Pulmonary Barotrauma

- Causes:
  - Holding breath while ascending with compressed air in lungs
  - Air trapped in part of lung from mucus plug or lung defect



Lung injuries are urgent medical emergencies

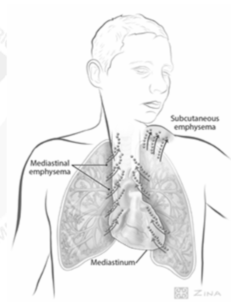
Pulmonary Barotrauma



- Types:
  - <u>Mediastinal emphysema</u>: Air in middle of chest
  - <u>Subcutaneous emphysema</u>: Air under skin at base of neck
  - <u>Pneumothorax</u>: Air in chest cavity - simple or tension
  - <u>Arterial gas embolism</u>: Air bubble in artery blocking circulation

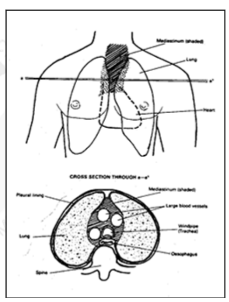
Mediastinal Emphysema

- Cause:
  - Over-pressurization of lungs resulting in a tearing of the alveoli allowing gas to escape into the tissues surrounding the lung. Gas tracks along the lung tissues to the area under the breastbone



Mediastinal Emphysema

- Effect:
  - Air expanding in middle of chest may affect circulation and breathing



Mediastinal Emphysema

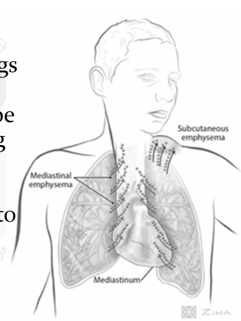
- Signs & symptoms:
  - Sudden, severe pain in chest
  - Shortness of breath
  - Possible fainting
  - Difficulty breathing

Mediastinal Emphysema

- Treatment:
  - CAB
  - Administer oxygen and monitor for shock
  - Examine diver for other signs of pulmonary barotrauma
  - Mediastinal emphysema causing respiratory or circulatory impairment may require recompression

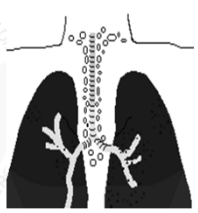
Subcutaneous Emphysema

- Cause:
  - Over-pressurization of lungs resulting in a tearing of the alveoli allowing gas to escape into the tissues surrounding the lung. Gas tracks along the lung tissues to the area under the breastbone then to the neck region



Subcutaneous Emphysema

- Effect:
  - Air expanding under skin at base of neck may affect swallowing, talking, and breathing



Subcutaneous Emphysema

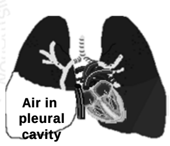
- Signs & symptoms:
  - Skin crackles when squeezed
  - Fullness in neck
  - Voice change
  - Swallowing, talking, breathing difficulties

Subcutaneous Emphysema

- Treatment:
  - CAB
  - Administer oxygen and monitor for shock
  - Examine diver for other signs of pulmonary barotrauma
  - Recompression not normally required

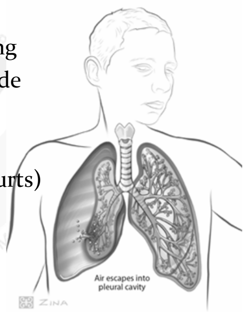
Pneumothorax

- Simple Pneumothorax:
  - Cause: Lung over-pressurization resulting in a one-time leakage of air into the pleura space between the lungs and chest wall
  - Effect: Lung partially collapses
- Tension Pneumothorax:
  - Cause: Air continues to enter but not exit the chest cavity with each successive breath thus progressively enlarging the air pocket
  - Effect: Lung totally collapses - expanding air exerts pressure on heart, trachea, esophagus, etc.



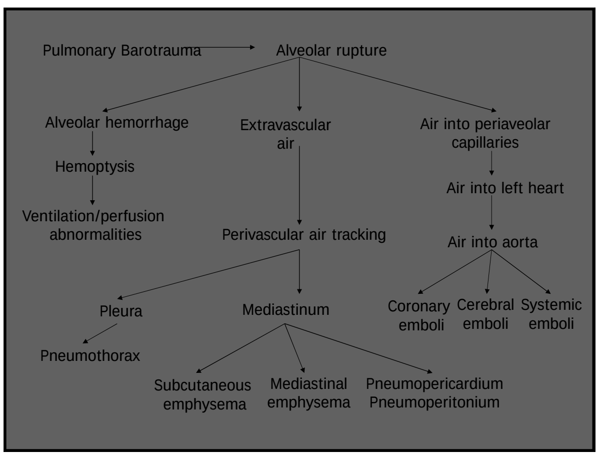
Pneumothorax

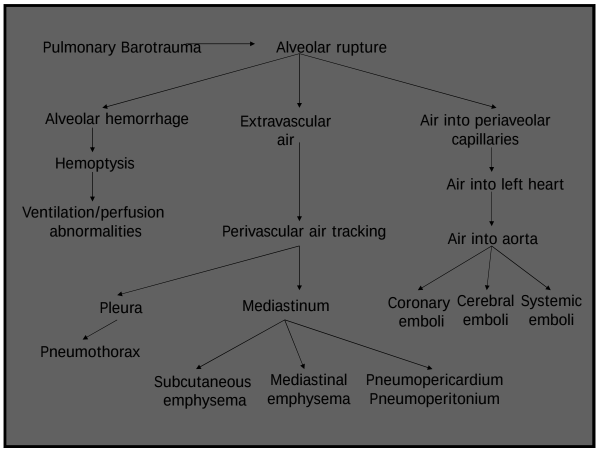
- Signs and symptoms:
  - Difficulty or rapid breathing
  - Leaning toward affected side
  - Hypotension
  - Cyanosis & shock
  - Chest pain (deep breath hurts)
  - Shortness of breath
  - Decreased or absent lung sounds on affected side
  - Death



Pneumothorax

- Treatment:
  - Simple Pneumothorax:
    - Normally improves with time as air is reabsorbed
    - Monitor for signs of tension pneumothorax
    - Monitor ABC's and administer oxygen
    - Transport to nearest medical facility
  - Tension Pneumothorax:
    - Position patient on injured side
    - ABC's
    - Treat for shock & administer 100% oxygen
    - Transport immediately to nearest medical facility (air must be vented from chest cavity)

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Alveolar rupture
Alveolar hemorrhage
Extravascular air
Air into periaveolar capillaries
Hemoptysis
Air into left heart
Ventilation/perfusion abnormalities
Perivascular air tracking
Air into aorta
Pleura
Mediastinum
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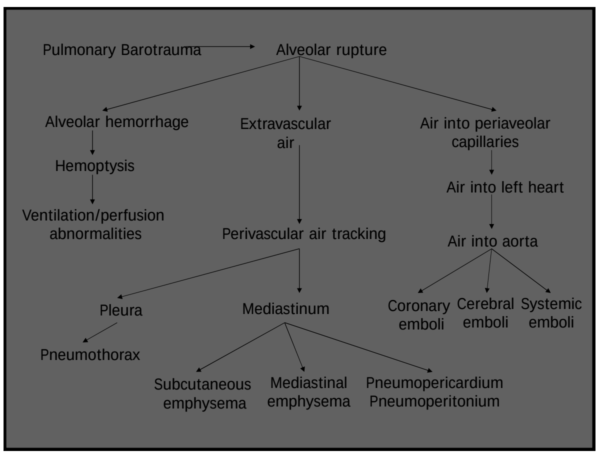
Pneumopericardium
Pneumoperitonium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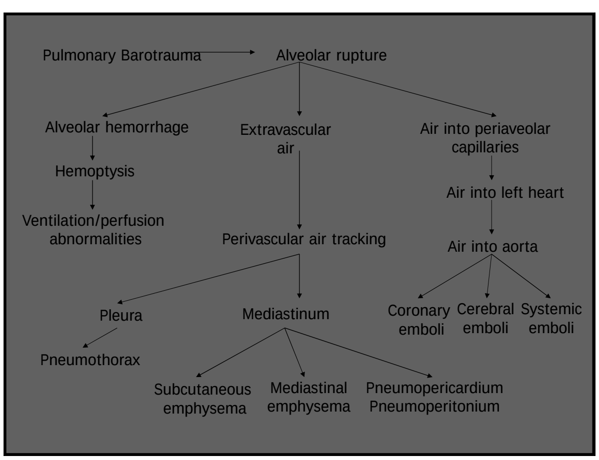
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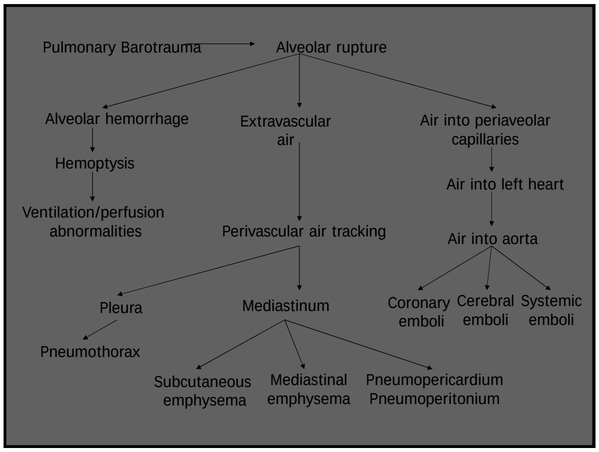

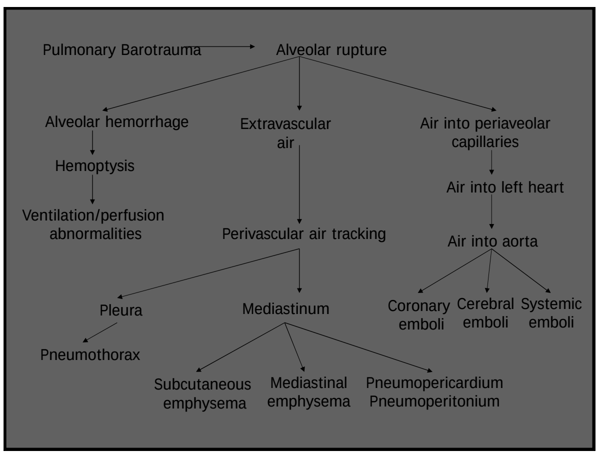
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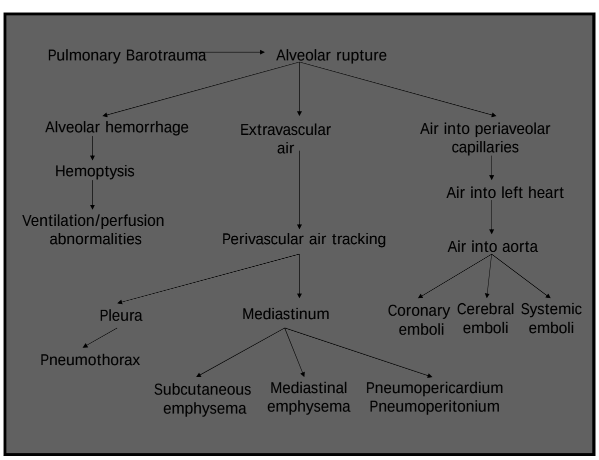
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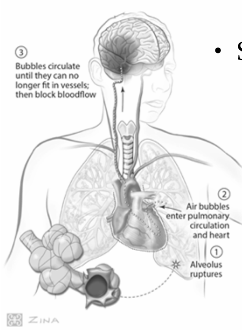
Arterial Gas Embolism

- Cause:
  - Over-pressurization of lungs resulting in the tearing of alveoli allowing gas to enter the blood circulation. Bubbles are conducted to the left side of the heart then to other parts of the body through the arterial circulatory system
- Effect:
  - Air bubbles block arteries--usually in brain

Arterial Gas Embolism



- Signs & symptoms:
  - Disturbances of the brain function
    - Sensation (i.e. numbness or tingling)
    - Movement (i.e. paralysis or weakness)
    - Vision
    - Speech
    - Balance or coordination
  - Chest pain
  - Shortness of breath
  - Bright red frothy sputum

Gas Embolism

- The entry of gas into vascular structures
- Common iatrogenic problem
- Can occur from procedures in almost all specialties
- Potential for serious morbidity/mortality
- Usually gas embolism = air embolism
  - Occasional carbon dioxide, nitrogen, helium
- Venous
- Arterial

Mechanisms of Gas Entry

- Extracorporeal-bypass circuit operations
  - Air entering circuit
  - Incomplete removal of air from heart after cardioplegic arrest
  - Carbon dioxide-assisted harvesting of peripheral veins
- Pulmonary barotrauma
  - SCUBA
  - Positive pressure mechanical ventilation
- Rupture of intaaortic balloon

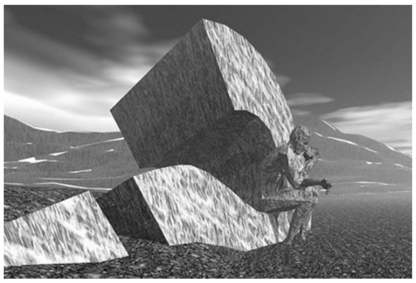
Arterial Gas Embolism

- Treatment – Hyperbaric Oxygen
  - The patient breaths 100% oxygen at a pressure above that of the atmosphere at sea level
  - Reduces the size of the bubble by raising the ambient pressure
  - Reduces the size of the bubble by increasing the oxygen window
    - Enormous diffusion gradient for oxygen into the bubble and for nitrogen out of the bubble
  - Arterial partial pressure of oxygen of greater than 2000 mm Hg is common
    - Increases the extent of oxygen diffusion into the tissues

Arterial Gas Embolism

- Treatment – Hyperbaric Oxygen
  - Proposed benefits
    - Prevent cerebral edema by reducing the permeability of blood vessels while supporting the integrity of the blood-brain barrier
    - Diminish the adherence of leukocytes to damaged endothelium (Thom 1997)
  - Considered to be first-line treatment of choice for arterial gas embolism as soon as cardiopulmonary stabilization has been achieved

Questions?



Recompression Tables and Strategies

Basic principles

- Increase ambient pressure to reduce bubble size
- Maximize inert gas gradient
- Minimize tender risk of injury

Recompression Treatment

- How late after onset of symptoms do we treat ?
  - Nobody really knows
  - Clinical response to treatment days after onset of symptoms Vann, Lancet 337, 2011
  - Up to 2 weeks out, significant improvement
  - Longer intervals ??
  - Short Tx delay more important in mild DCI Severe cases should get transferred to best facility
    Ross UHMS ASM 2007

Monoplace

- Suitable for DCI treatment
- 140 patients reported with complete recovery
  - DCS I 98%, II 95%, III 100%, AGE 94%

Cianci ASEM 77(10), 2006

Hart-Kindwall protocol

- Descend as quickly as possible to 2.8 ATA
- 100% O_2 for 30 minutes
- Decompress to 2 ATA over 30 minutes
- 100% O_2 for 60 minutes
- Decompress to surface over 30 minutes
- No air breaks
- Oxygen dose 401.7 UPTD

Monoplace

- Should have a BIBS system for air breaks
- Most chambers are rated to only 3 ATA
- Long treatment, anxious patient alone in the tube
- No neuro-examination during treatment
- Can't go deeper
- Usually no mixed gas capability

Multi-place chamber

- Easy access to the patient
- Performance of procedures during treatment
- Re-examination in the chamber
  - Important to assess residuals
- Pressure rated to greater depth
- Different gas mixtures to BIBS
- Puts tender at risk for DCI

Treatment Tables

- Derived by educated guess
- **Field tested !!!!** and fine tuned
- Developed by USN, RN, COMEX etc.
  - For their divers !!!
  - Failure rates may be higher in other populations

Lee JHM 6(1), 1991

- Provide pressure / time / gas profile
- They treat the patient's illness
- Provide tender decompression algorithm

Air Treatment Tables

- Air as chamber gas and breathing gas
- Take long time
- High failure rate
  - (up to 47% in recreational divers USN TT4)
  - Only 6% when originally used for USN divers

Cianci, Slade ASEM 2006

- Used for saturation treatments

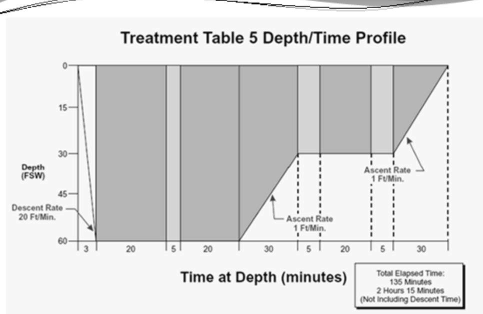
Oxygen Treatment Tables

Most widely used

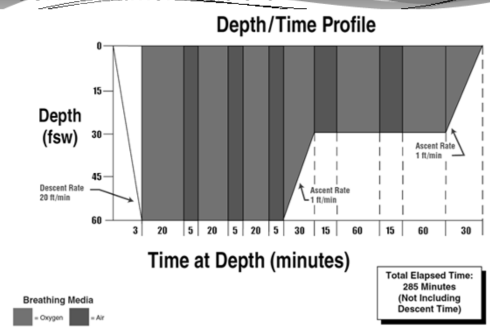
- Low relapse rate, good track record
- O_2 as breathing gas or chamber gas (mono)
- No on-gassing of inert gas
- HBO inhibits white cell adhesion
  - Hyperbaric air or normobaric O_2 does not
  - For life of leucocyte (24 hrs) ⇒ serial treatments
- Oxygen toxicity risk ⇒ air breaks
- Provides large inert gas gradient

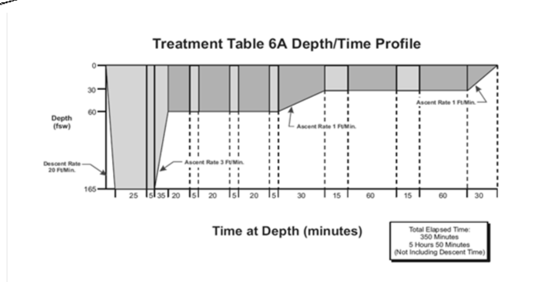
Mixed Gas Treatment Tables

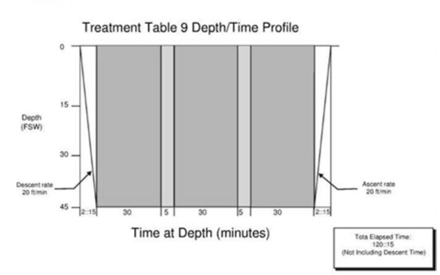
- Used for "deeper" treatments to dilute O_2
- Use Heliox or Nitrox as breathing and/or chamber gas in various mixtures
- Incurs an inert gas load
- Complex dynamics and kinetics
  - Counter diffusion superficial or deep
- Gas switching may have benefits ?
- ex: COMEX 30 (with it's many variables)

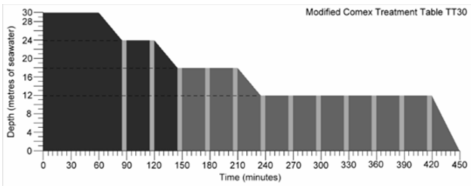


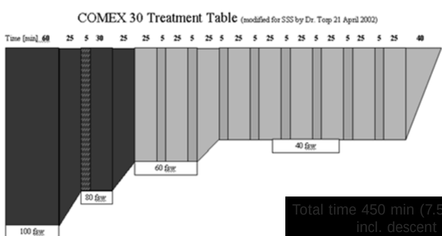
USN Treatment table 6







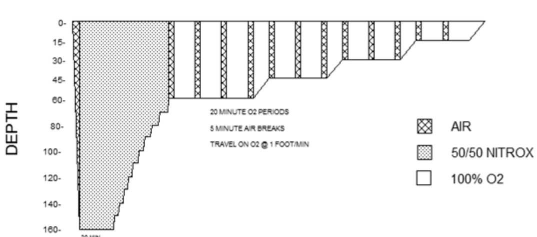




[redacted]

HTC 160 FSW TREATMENT TABLE

3/2/2/2

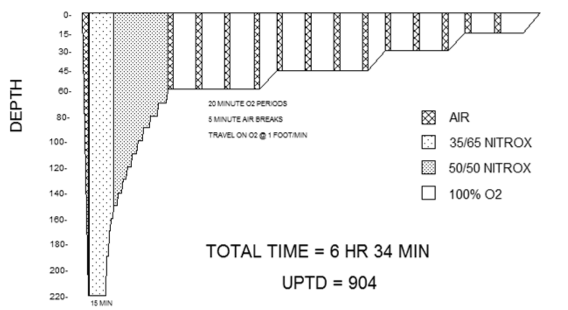


TOTAL TIME = 6 HR 18 MIN

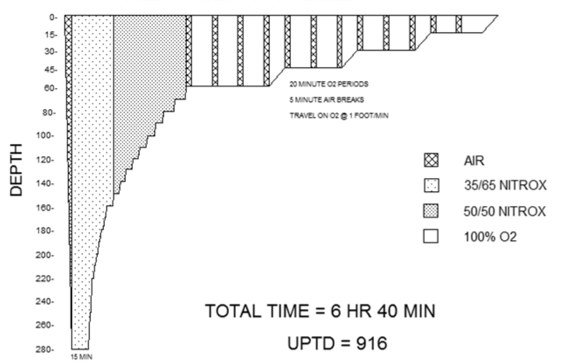
UPTD = 887

HTC 220 FSW DUAL NITROX TREATMENT TABLE

3/3/2/2



HTC 280 FSW DUAL NITROX TREATMENT TABLE



Pain only bends

- Re-compress to 60 fsw
- Evaluate patient at depth
- If symptoms disappear after 10 min $\Rightarrow$ TT5
- If no resolution of symptoms finish on TT6

Skin bends

- Minor isolated skin lesions ⇒ USN TT5
- Skin rash can be associated with PFO
  - Extra careful neuro
- Cutis Marmorata
  ⇒ use USN TT6
  - High bubble load

Mild neurological DCI

- Initial treatment USN TT6
- Followed by a USN TT6 within 8 – 12 hrs
  - If still symptomatic
- Follow with USN TT5 once or twice / day
  - Some use 18/60/30 (2.8 ATA for 60 min and 30 min to the surface)

How long to treat ?

- Treat until no more improvement for 2 successive treatments
  - Symptoms can wax and wane
- Washout treatment for returning to diving or anticipated pressure change is debatable
  Bennett MH, et al. Undersea Hyperbaric Med 30(3) 2003
  - If not sure of complete resolution
- Consider what you are treating
- Average number of treatments 2-3

Follow-up treatments
2.4 vs. 2.8 ATA

- USN TT9 will give you less of a PpO_2
- Retrospective study: 50 patients TT5, 15 patients TT9. Severity was reported similar.
- All received TT6 as initial treatment.
- Total # of Rx & chamber time did not show a statistically significant difference
- Relapse 8/50 (6%) of TT5 and 6/15 (40%) in TT9 group ($p=0.032$)

Wilson et al. Unders Biom Res 16(suppl) 87-88, 1989

Severe neurologic DCI

Motor involvement, inability to void etc.

- Recompression should take priority over most investigations and paperwork
- Know your limitations
  - Gas supply, Chamber rating, Personnel
- Start at 60 fsw, evaluate during 1st air break
- If improvement **Strongly !** **consider extensions at 60 fsw**
- Aim for full recovery during 1st treatment
  - 80% may be more realistic
- Don't under-treat (don't exaggerate either)

Treatment "Failures"
No improvement at 60 FSW

- Give extensions per TT instruction
- Strongly consider going to deeper table
  - COMEX 30 (or TT6A on mixed gas)
  - Hawaiian Spike RW Smerz *UHM 2005, Vol. 32, No. 5*
- If recurrence of symptoms on the slide up, **go back to 60 fsw** (or deeper) and give extensions
- Patients can get worse in the chamber
  - Because of the disease process, not because of the chamber treatment

Treatment "Failures"

- If patient still has severe symptoms, consider back-to-back USN TT6
- Consider deep table (if you can)
- Saturation table (if you can)
- Do the best you can for the patient !!
- Know chamber/gas/personnel limitations
- **Remember the tender !!!!!!**

Treatment of DCS during saturation dives

- You are usually part of a bigger dive operation
- Usually occurs during upward excursion
- The surface is not an option
- Principals are the same than other tables
  - Increase pressure
  - Maximize diffusion gradient for the inert gas
  - Try to minimize risk for tender (other divers)

Treatment of DCS I during saturation dives

- DCS I occurring > 60 min after excursion
- Compress to depth of distinct improvement
  - 5 fsw increments at 5 fsw/min
- Alternate PpO_2 1.5 – 2.8 ATA by BIBS for 25 min with 5 min of chamber gas
- Remain at depth for 2 hours after resolution of symptoms
- No more upward excursions

USN Dive Manual Rev 6

Treatment of DCS II during saturation dives

- or DCS I occurring < 60 min after excursion

- Compress at 30 fsw/min to storage depth
  - or depth from which excursion started
- If not related to upward excursion compress to depth of distinct improvement
  - 5 fsw increments at 5 fsw/min
- Alternate PpO_2 1.5–2.8 ATA by BIBS for 25 min with 5 min of chamber gas for 2 hrs
- Remain at depth for 12 hours after resolution

USN Dive Manual Rev 6

Don't just focus on one issue Look around you !!

Paraplegic patient

- DVT prophylaxis (PE after successful recompression)
- Urinary catheter
  - UTI, bladder training
- Functional ileus
- Physical therapy
- Prolonged HBO therapy (up to 40-50 Rx)
  - Oxygen toxicity, Lens refraction changes
- Don't be shy to ask for consults

Unconscious Diver

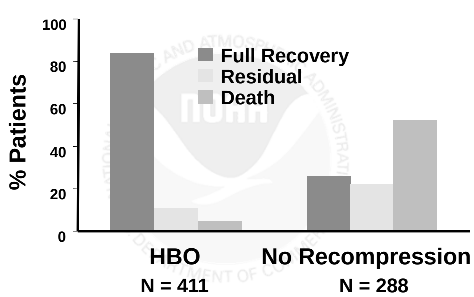
CAGE ?

- Treat with TT6 (? even if asymptomatic)
  - About 50% may progress or relapse
- USN treats divers asymptomatic after O_2
- TT 6A with Nitrox/Heliox if no improvement
- If comatose
  - Secure the airway and ventilate
  - I.V., Urinary catheter, Tympanocentesis
- If the patient wakes up at depth
  - Either need for sedation or extubation
- Need qualified tender

Critical Care in Chamber

- Ventilation
  - Manual ventilation on pressure change
  - Check and adjust mechanical ventilation parameters to ambient pressure
- Fill ET Tube balloon with saline
- Increased work of breathing through ETT
- Procedures for handling of oxygen waste
- IV drip chamber level change with pressure
- Leave BP cuff valve open

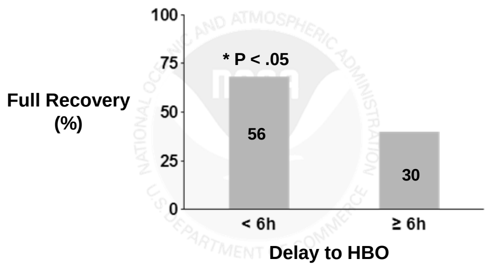
Effect of HBO on Outcome after AGE



Dutka, 1991

Timing of HBO for Iatrogenic AGE

N = 86



Blanc P et al. Intensive Care Med 28:559, 2002

Initial Treatment Table USN 5 or 6

Author	N	Relief: Complete (%)	Relief: Substantial (%)	Comments
Workman (1980)	*150*	*85*	*95*	*After 2nd rx*
Pearson & Leitch (1972)	*28*	*67*	*83*	
Davis (1977)	*145*	*98*		*Altitude DCI*
Erde & Edmonds (1975)	*106*	*81*		
Bayne (1978)	*50*	*98*		
Kizer (1979)	*157*	*58*	*83*	*Long delays*
Yap (1980)	*58*	*50*		
Gray (1984)	*812*	*81*	*94*	
Green (1989)	*208*	*96*		*All type I (USN 5)*
Ball (1993)	*14*	*93*		*Mild*
	11	*36*		*Moderate*
	24	*8*		*Severe*
TOTAL	*1763*	*80*		

Omitted decompression

- For staged decompression dive profiles
- Asymptomatic patient
- USN TT5 for < 30 min missed deco
- USN TT6 for > 30 min missed deco
- If symptomatic treat like DCI

"Bends watch"

- Chamber attendants after TT to stay 1h
- For patients:
- Non-decompression dive profiles with uncontrolled ascent
- For symptoms not likely to be DCS
  - 35% improved with recompression

Cianci, Slade ASEM 2006

- Requires patient to stay close to facility
- Tender/Operator standby

"Test of pressure"

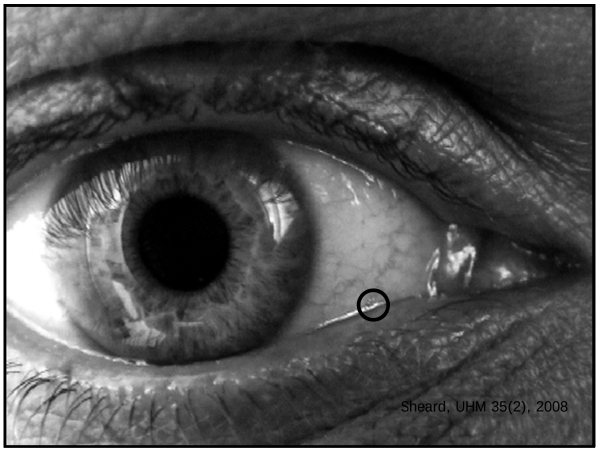
- For chamber attendants:
  - Can a tender tolerate and function in the hyperbaric environment
- For equipment:
- For patients who have symptoms that may not be related to DCI:
  - USN TT6
    - (other standard first line TT have been used)
  - 35% responded to recompression

Cianci, Slade ASEM 2006

DCI in Breath-Hold Diving

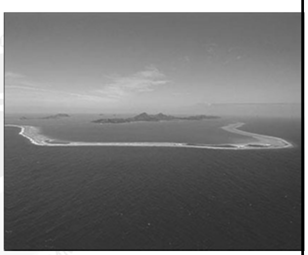
- Taravana ("to fall crazily") in Tuamotu
- Describes symptoms of DCI in pearl divers
- Repetitive deep dives 60-100 ft
- Very short surface intervals (1 min)
  - Ultrasounds detects bubbles Spencer, Fed Proc 1972
- Case reports in the Royal Danish Navy
  - Supported by M value calculations for N_2
- > 90 cases in the literature
- Successful treatment with recompression

Paulev JAP 1965 and 1967, Wong DHM 36(3) 2006



Tuamotu

Mangareva



No Tarawana in Mangareva (>10min SI)

Nausea Vertigo Nystagmus

Inner Ear DCS

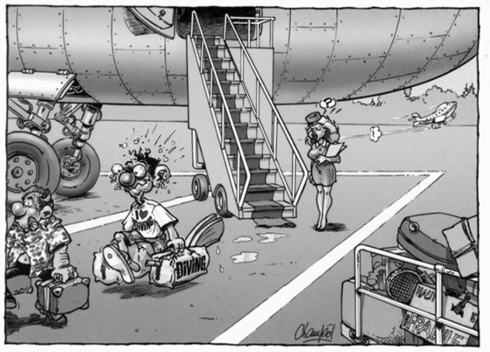
- Isolated inner ear DCS on Air or HeOx
- Can be associated with hemorrhage
- During or after surfacing
- Needs recompression
- Other side compensate
- Needs follow-up !!!

Inner Ear Barotrauma

- Symptoms usually on the way down
- Equalizing problems
- Round or oval window rupture
- Avoid Valsava maneuver
- Head elevated, bed rest

If in doubt, myringotomy and recompression

Flying after Diving or Treatment



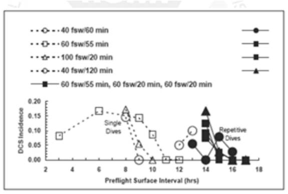
Flying after Diving Guidelines

UHM 2004, Vol. 31, No. 4 – Flying after diving

Experimental trials to assess the risks of decompression sickness in flying after diving.

R.D. VANN[1,2], W.A. GERTH[3], P.J. DENOBLE[1], C.F. PIEPER[4], AND E.D. THALMANN[1,2]

[1]Divers Alert Network, Department of Anesthesiology, Duke University Medical Center, Durham, NC; [2]Center for Hyperbaric Medicine and Environmental Physiology, Department of Anesthesiology, Duke University Medical Center, Durham, NC; [3]U.S. Navy Experimental Diving Unit, Panama City, FL; [4]Center for Aging, Division of Biostatistics, Department of Community and Family Medicine, Duke University Medical Center, Durham, NC



Vann RD, et al. *Undersea Hyperb Med* 31:431, 2004

Flying after Diving
Commercial North Sea

- No stop dives less than 60 min / 12 hrs
  - 2 hrs (600 feet) 8 hrs (8000 feet, short flight)
  - 24 hrs (8000 feet long flight)
- All other < 4 hrs or HeOx > 4 hrs
  - 12 hrs (600 feet) 24 hrs (8000 feet)
- All others > 4 hrs
  - 24 hrs (600 feet) 48 hrs (8000 feet)

DMAC 07 Rev 1 – March 2001

USN Dive Manual Rev **6**
Required Surface Interval Before Flying to 8,000 Feet

Repet Group	Old Time (Rev 5)	New Time
C	0:00	0:00
D	3.28	1:45
G	12:05	9:13
J	17:35	14:13
M	21:37	18:00
Z	24:00	21:01

NAVSEA Flynn 2009

Flying after Saturation Dive

- 48 hrs

NOAA dive manual

- 72 hrs

USN dive manual

- Gas bubbles detectable after 9 fsw saturation
- Case of neurological DCI during flight (2 hrs) 18 hrs after surfacing from 15 fsw saturation

Wells personal communication

Flying after Treatment

- Various recommendations 24 hrs – 42 days
  - 42 days retrospective data Townsville Australia
- Will have significant impact on patient
  - End/cost of vacation, not able to return to work
  - Relapse in an airplane (60000 SFR for unscheduled landing)
- Cost of re-treatment in home country
  - Who pays for that

Flying after Treatment

- ? Residual bubbles
  - "Evidence supports existence of bubbles for some days or weeks post DCS and recompression therapy"

    Edmonds: Diving and Sub aquatic Medicine 4th ed. 2002
- Hypoxia during flight
  - Oxygen during flight may be an option
- Few studies addressing this issue

DAN data

- Relapse of symptoms without flight 4%
- Relapse with flight in asymptomatic patients 10%
- "Relapse" in symptomatic patients 71%
  - 45% if flight > 72 hrs

    DAN data presented at Remote Location Workshop 2004

No fly period Royal Navy

- DCS 1 resolved TT61 or Surf O_2 48 hrs
- DCS 2 resolved single TT62 72 hrs
- All others 7 days to 6 weeks

No fly period USN

- Complete relief after treatment for DCS or AGE should wait 72 hrs at a minimum
- Patient with residuals consult DMO

- Tender in USN TT 1A, 2A, 3, 5, 6, 6A should wait 24 hrs
- Tender in USN TT 4,7,8 wait 72 hrs

USN Dive Manual 5th ed

No fly period NOAA

- Patient
- Type 1 24 hrs
- Type 2 48 hrs
- TT4 or 7 72 hrs
- With residual symptoms 72hrs (contact DMO)
- Tender
- TT5, 6, 6A, 1A, 2A, 3 12 hrs
- TT4 or 7 48 hrs

NOAA dive manual

Flying after DCI
Diving Medical Advisory Committee

- "Flying in the presence of even minor symptoms or residua of DCI carries a considerable risk of provoking serious neurological illness"

DMAC 07 Rev1 - March 2001

Flying after DCI
Diving Medical Advisory Committee

- Following therapy for DCI, advice should be sought from a diving medical specialist
- Complete resolution after 1st recompression 24 hrs for 2000 feet or 48 hrs for 8000 feet
- All others wait as long as possible

DMAC 07 Rev1 - March 2001

DCI in flight
Diving Medical Advisory Committee

- DCS Type 1:
- Oral fluids, analgesics, oxygen
- Continue flight
- DCS Type 2:
- Consult diving medical specialist
- Oral fluids, oxygen, increase cabin pressure

TV series "House"

- May need to divert plane

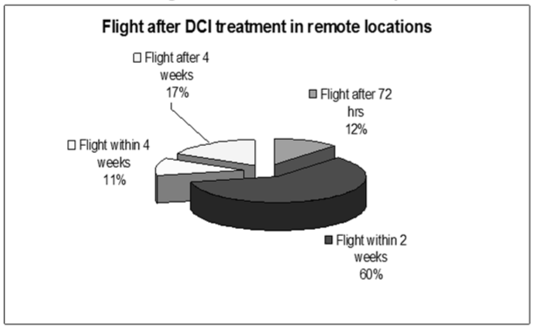
DMAC 07 Rev1 - March 2001

Flying after DCI follow-up study

- 93 consecutive patients contacted from 2003-Aug 2005
  - 4 unable to contact
- D/C without residual symptoms (78) 83%
- D/C with residual symptoms (15) 17%

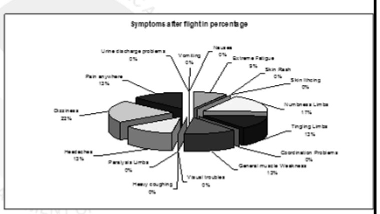
Torp, Schaper EUBS Annual meeting Barcelona 2005

Time to flight after recompression



Symptoms after flying

- 16 (17%) had symptoms after the flight (mean 10 hrs)
  - 50% D/C with residuals
  - 50% no pre- flight symptoms
  - (10% of those D/C'd without Symptoms)



Conclusion

- D/C with symptoms higher likelihood for symptoms during flight
- 67% will/want to fly home ≤ 2 weeks
- None of the symptoms were severe
- Few patients had to be referred for HBO
  - 3/16 were referred to HBO facility
  - 2 had further HBO treatments for persistent paresthesias/numbness

Return to Diving after Treatment

- Primary concern for dive professionals
- Guidelines for USN, commercial divers
- No guidelines for Dive instructors/masters
- If complete resolution after “deserved hit”
  - 4 weeks for neuro DCI
- If incomplete resolution don’t dive
- If undeserved hit need further evaluation
- Spont. Pneumothorax should not dive again

Complications of HBO

Pulmonary Barotrauma

- Uncommon as result of HBO < 0.001 %
- Can be present prior to HBO
- Can be missed on chest x-ray
- No problem on descent (volume compressed)
- On ascent, volume expands creating

Tension Pneumothorax

- Unable to bring the patient to the surface

Signs & Symptoms

- Dyspnea, Cough
- Crepitus
- Distended neck veins
- No breath sounds, Tympanic percussion
- Deviated trachea
- Tachycardia
- Collapse

Treatment

- Descend
  - Compress the volume
- Diagnose
  - Physical exam
- Drain
  - Convert to open pneumothorax
  - Connect to one way valve

Otic Barotrauma

- Incidence up to 10%
- Less common in divers than in HBOT
- Hold descent, come up a little, go slow
- Nasal decongestant
- No pseudoephedrine tablets in DCI
- May need tympanocentesis

Pulmonary Oxygen Toxicity

- "Not uncommon"
- Burning sensation
- Shorter Oxygen periods
- More frequent air breaks
  - Catalina break-up 25/5 @ 30 ft or 10/5 @ 60 ft
- If that extends the table, provide additional oxygen periods for the tender
- No air breaks during the slide

CNS Oxygen Toxicity

- Uncommon (< 0.02 %)
- Often premonitory signs but not always
- Treat with chamber air
- **Do not ascend during seizure !!!**
- Closed glottis causes pulmonary barotrauma
- Retry oxygen once 15 min after symptoms subsided ± Valium
- If repeat seizure finish TT shallower
- Remember the tender when TT extended

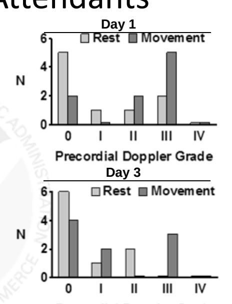
DCI in Tender

Uncommon 0.2%

- Can happen even in "short" TT5
- Tender should be well hydrated
- Should promote circulation to limbs
- If tender experiences symptoms you now have an extra patient
- No flight after:
- TT5,6,6A,1A,2A,3 12 hrs NOAA 24 hrs USN
- TT4,7or 8 48 hrs NOAA 72 hrs USN

VGE in Chamber Attendants

- **Incidence up to 0.76%**
- **2.4 ATA air 90/100 minutes after 10 min compression**
- **100% O2 decompression**
- **N=9, Age 52 ± 8 yrs female**
- **One exposure / day for 3 days**
- **N=28 Age 39 ± yrs 9 male 19 fem**
- **163 measurements**
- **10% KM grade III-IV**
- **Risk factor age, fem, BMI, frequency**



Risberg J, et al. *UHM* 31:417, 2004

Cooper et al. DHM 6, 2009


Questions ?

Medication Administration

Introduction

- #1 Principle: Do No Harm
  In other words – do you need to do anything invasive?
- All medical procedures have complications – some are **life-threatening**

General Principles

- Skin deters infection. Invasive techniques violate the skin, therefore set the stage for infection
- So…Use "clean technique" to decrease this concern.
- Body fluids are dangerous. Use universal precautions/PPE

Drug Absorption Rates

- Intravenous.....................Immediate
- Sublingual.......................Rapid
- Endotracheal..................Rapid
- Intramuscular.................Moderate
- Rectal...............................Moderate
- Enteral (oral)..................Slow
- Transdermal (skin)........Slow

Subcutaneous Injections

- Administration route for insulin and Lovenox injections
- Lovenox preloaded in syringe with needle attached
- Use insulin syringe with unit and cc markings

  1 cc = 100 units regular insulin
- Preferred injection sites are upper abdomen and anterior surface of thighs.

Subcutaneous Injections

- Additional sites include iliac crests and outer aspects of upper arms.
- Rotate sites if repeated injections required
- Cleanse skin with alcohol pad prior to injection
- Pinch the skin and inject at **90**°angle to skin fold
- Massage site lightly to enhance absorption

Intramuscular Injections

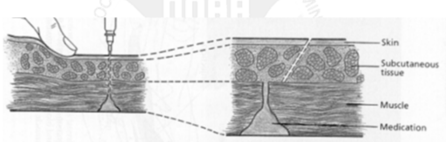
- Most common method for injecting medications
  - Toradol, immunizations (Hep A & B, Td), ATB
- Absorbs in 10 to 30 minutes unless injected into blood vessel directly (aspirate before injecting)
- Inject at a **90º** angle to skin
- Needle size usually **1 ½ inches** and **18 - 21 gauge**
- Up to **5 ml** can be given into a large muscle.

Intramuscular Injections

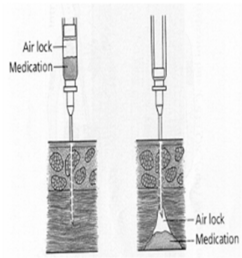
- Over **3 ml** may be uncomfortable for the patient
- Inject slowly: speed = pain
- Anterior lateral thigh and deltoid are preferred sites
- Thigh for large volumes & deltoid for small volumes
- Avoid deltoid if under developed or small person

IM Injection: The Z - Track

- The Z - Track method of injection prevents the deposit of medication through sensitive tissues



IM injection -The Air Lock

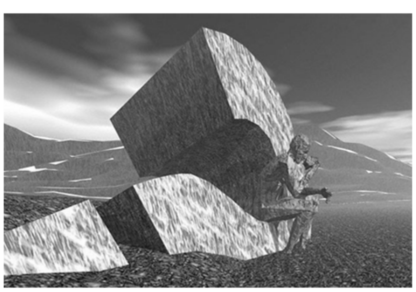


- Administering IM injection by the air-lock technique prevents tracking of medication through SQ tissues.

Remember

- All body fluids are dangerous.
- Blood is the most dangerous one.
- **Be careful with sharps!!!**

Questions?



Intravenous Therapy

Welcome to Seattle!!

2

Techniques and Administration

- Equipment must be kept clean.
- Assemble equipment before starting IV.

IV Solutions

Administration Sets

Administration sets move fluid from the IV bag into the patient's vascular system.

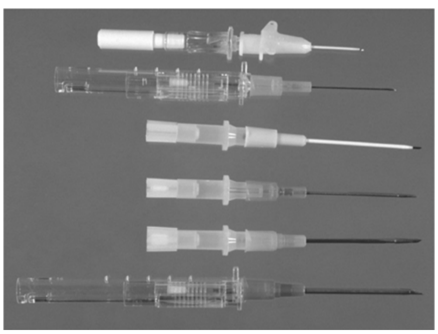
Drip Sets

- Number refers to number of drops per milliliter.
- Either microdrip or macrodrip

Preparing an Administration Set

1. Remove rubber pigtail.
2. Remove cover from spike.
3. Slide spike into port.
4. Run fluid through tubing.
5. Twist cover to let air escape.
6. Fill drip chamber half way.
7. Hang bag.

Catheters



Saline Locks

Maintain IV site without running fluid

Preparation is the Key

- Get **EVERYTHING** setup first (opened and easily accessible)
- Have an assistant (you trust) when possible

10

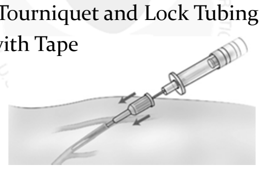
Materials Needed

- Absorbent disposable sheet (chuck or towel)
- 2 alcohol wipes
- Tourniquet
- Angio Catheter (16, 18, or 20 gage)
- IV tubing (Macro or Micro Drip)
- 30cc syringe filled with 30cc normal saline
- 4 pieces of tape which has been precut to approximately 4 inches (10cm) in length and taped conveniently to the table or side of bed.
- Rubber gloves
- Gauze (several pieces of 4x4 or 2x2)

11

Step Wise Approach

- Apply tourniquet high on the upper arm
- Search for suitable distended subcutaneous veins and clean with alcohol pad
- Puncture Vein (flash back) and Advance Plastic Catheter
- Release Tourniquet and Lock Tubing Connection
- Secure with Tape
- Test IV



12

Securing the Line

- Prepare tape before inserting catheter.
- Create a loop.
- Do not tape around extremity.

IV Video

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Complications

- Failure to get venous access
  - "blown vein" ex…
- Uncooperative patient
- Fluid overload
- Phlebitis, Cellulitis, and Sepsis
- Equipment failure

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Complications

- Reactions may be local or systemic.
- Local reactions are limited.
- Systemic reactions involve other body systems.

Infiltration (1 of 2)

- Escape of fluid into surrounding tissue
- Caused by:
  - Catheter passing through vein
  - Improper catheter placement
  - Patient movement
  - Tape securing site loosened

Infiltration (2 of 2)

- Signs and symptoms
  - Edema/tightness
  - Slow flow rate
- Correction
  - Remove IV.
  - Apply direct pressure.

Phlebitis

- Inflammation of the vein
- Causes
  - Nonsterile equipment
  - Prolonged IV therapy
  - Irritating IV fluids
- Watch for fever/tenderness/red streaking.
- Discontinue IV.

Occlusion

- Physical blockage of vein or catheter
- Can be caused by insufficient fluid flow or patient movement
- Watch for slow flow and blood in tubing.

Vein Irritation

- Can be caused by rapid infusion rate
- Watch for redness and phlebitis.
- Discontinue IV.

Hematoma (1 of 2)

- Accumulation of blood
- Watch for blood pooling around IV site.
- Apply direct pressure.

Hematoma (2 of 2)

Hematomas can be caused by improper removal of a catheter, causing tenderness and pain.

Allergic Reactions

- Sensitivity to IV fluids or medications
- May be mild or result in anaphylaxis
- Discontinue IV.
- Monitor IV.

Air Embolus (1 of 2)

- Air introduced into circulatory system
- Improperly prepared or monitored IV

Air Embolus (2 of 2)

- Signs and symptoms
  - Shock
  - Respiratory distress/arrest
- Correction
  - Place patient on left side with head lowered.

Catheter Shear

- Portion of catheter is shaved off.
- Caused by improper insertion technique
- Watch for sudden shortness of breath.

Circulatory Overload

- Too much fluid delivered to patient
- Unmonitored IV administration
- Watch for respiratory difficulty and edema.
- Slow IV, raise patient's head, and administer high-flow oxygen.

Vasovagal Reactions

- Reaction to needles or sight of blood
- Watch for syncope and anxiety/diaphoresis.
- Treat for shock.

Troubleshooting Problems

- Check:
  - Fluids
  - Administration set
  - Height of IV bag
  - Type catheter
  - Constricting band

Your Patient is Watching

- Convey Confidence.
- Get an assistant that can get things or hold something during procedure.
- Make sure your patient is comfortable
- Be sensitive of the words you use to describe what you are doing when your patient is anxious.

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Bone Injection Gun

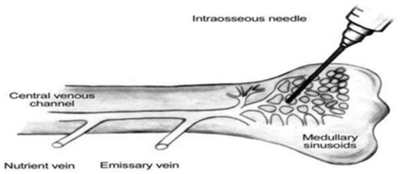
B.I.G.

INTRAOSSEOUS ACCESS

- Penetration of the bone in order to access the intravascular compartment
- Device inserted into medullary cavity
- Proximal tibia, distal tibia, proximal humerus, distal radius
- Appropriate for adult and paediatric application
- Temporising, emergency measure

Bone Structure

- Consists of hard outer layer (**cortex**)
- Covers fatty tissue, marrow and nerves
- Covers vascular cancellous bone at **distal ends** of long bone
- Vascular access by needle insertion into cancellous bone



Indications

- Difficult or impossible IV Access
- Appropriate for Adult or Paediatric application
- Urgent requirement for fluid and/or drug administration (Cardiac Arrest, Hypovolaemia, Shock)

CONTRAINDICATIONS

- Infection at insertion site
- Local fracture
- Existing trauma at insertion site
- Same bone osteomyelitis
- Ipsilateral femoral fracture
- Osteogenesis imperfecta
- Recent prior attempt in same bone
- Osteporosis

Complications

(Generic for all devices)

- Compartment Syndrome
- Osteomyelitis
- Local tissue infection
- Pain (most often with fluid infusion in awake patient)
- Improper placement

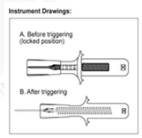
Bone Injection Gun

- Two devices
- Blue = Adults
- Red = Paediatrics (0-12 years)

Adult Bone Injection Gun

How it works

- Trocar and Cannula contained within blue plastic barrel
- Powered by spring loaded piston in white plastic handle
- Trocar and cannula propelled from barrel, into bone, when device is triggered



You will need …….

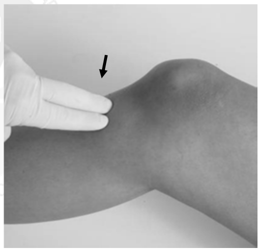
- Adult Bone Injection Gun
- Disposable dressing pack
- Skin clean up solution
- Gloves
- Adhesive surgical tape (1 cm wide)
- 10ml syringe
- 10ml Normal Saline
- Lidocaine
- Infusion set
- IV Fluid

Location

- Place a rolled towel under knee with the foot facing outward .
- Find the outset point :
- Tibial Tuberosity-
- A rounded protrusion
- distal to the patella.
- Locate the Tuberosity and feel it on your leg .

Location

- From the **Tibial Tuberosity**
- Go approx. 2 cm (1 inch) to the inner part of the leg to find a flat site.
- This is the ***Tibial Plateau***.



Location

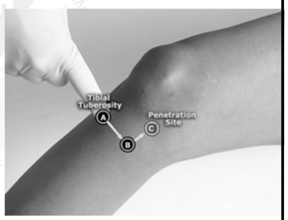
From ***Tibial plateau*** Go **UP** approx. 1cm (0.5 inch) toward the patella.

*You are looking for the thinnest portion of the cortex.

Correct Location Medial Aspect of the Proximal Tibia

Location

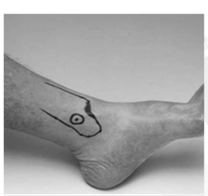
- **Summary** (adult patient):
- From Tibial Tuberosity Go
- approx. 2 cm (1 inch) **IN**
- (inner leg).
- And approx. 1 cm (0.5 inch)
- **UP** (toward patella).
- *Try to find the insertion site on your leg.



IMPORTANT

- The Bone Injection Gun must be held **FIRMLY** by the blue barrel against the selected insertion site
- It is important that the correct insertion site is selected
- You are aiming to penetrate the **THINNEST** part of the bony cortex

Alternate Adult Locations

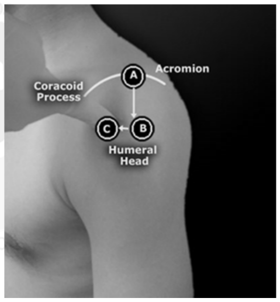


1-2 cm proximally to the base of the Medial Malleolus .

Posterior-Distal metaphysis of the Radius.

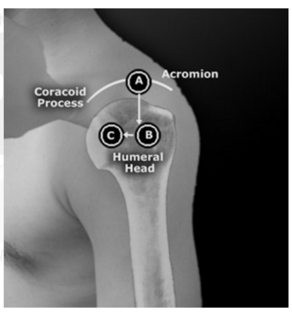
Head of Humerus

1. Draw the imaginary line connecting the Acromion and the Coracoid Process.
2. From the midpoint of the line, go 2 fingers Distally (This is the Humeral Head)
3. *In certain patients, in addition:*
4. *Go one finger Anteriorly (Toward the Chest)*



Head of Humerus

*Once the insertion site is located, confirm the exact position by verifying the Greater Tubercle's outer margins.



Setting Insertion depth

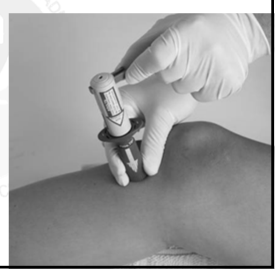
- Adjust blue barrel to determine depth of cannula insertion according to insertion site
- These sites are clearly marked on the B.I.G.
- Proximal tibia, malleolus, distal radius
- Proximal tibia setting applies for anterior humerus

Positioning

- With one hand holding
- blue barrel **firmly**
- against the selected
- insertion site……

Safety Latch

- Pull out the safety latch by squeezing the two ends together
- DO NOT DISCARD! It will later be used.



Important

- The red safety latch is **NEVER** removed **before** the B.I.G. is correctly positioned at the insertion site
- Do not discard the safety catch
- Used to stabilise cannula following insertion

Triggering

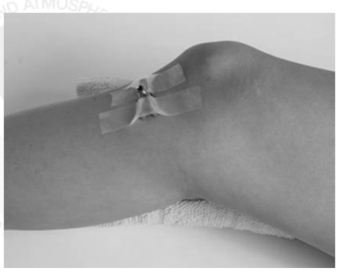
- While continuing to hold the bottom part firmly against the leg, Place 2 fingers of your other hand under the 'winged portion' and the palm of that hand on the top.
- Trigger the BIG by gently , but firmly pressing down .
- Extra force is not required.

Stylet Trocar

- Pull out the stylet trocar.
- Only cannula remains in the bone.

Fixation

- Remember the red safety latch?
- The safety latch provides additional stability.



Aspiration

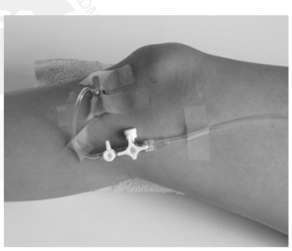
- Venous blood can be aspirated into a syringe for laboratory sampling.
- Lack of blood return **DOES NOT** mean the IO is improperly placed.

Flushing

- Flushing 10-20ml of saline is recommended before the injection of fluids or drugs.
- In conscious patients- consider local anaesthesia prior to administering fluids.

Administration

- Fluids and drugs may now be administered
- A pressure infusion cuff may be required
- *Optional :*
  - Connect a stopcock to the cannula and then use a standard I.V set.



Key Points

- IV is most rapid form of medication delivery
- IV is most rapid form of volume replacement
- Be prepared and take your time to do it right the first time
- Use IO fluid resuscitation only when you are unable to get an IV.
- Choose your IO site carefully

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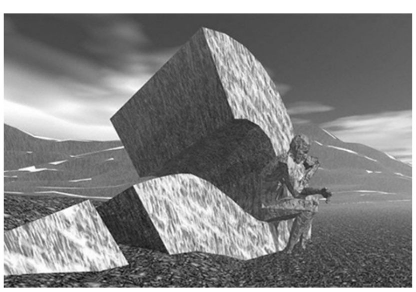
Questions?



Airway Management

NOAA Diving Medical Technician 2015

Learning Objectives

Respiratory Assessment	Be familiar with the primary indicators (signs and symptoms) for respiratory distress and arrest utilizing a quick assessment
Respiratory Arrest	Define respiratory arrest and understand the treatment basics
Ventilation & Oxygen for CPR	Simple things to remember when ventilating a patient during CPR
Airway Adjuncts	How and when to use adjunct airways
Oropharyngeal Airway (OPA)	Be familiar with and know how to use a OPA
Nasopharyngeal Airways	Basic instructions for insertion of Nasopharyngeal Airways

2

Introduction

- Airway management is an essential skill for DMTs caring for critically ill or injured patients and is fundamental to the practice of emergency management of a patient.

Non Oxygenated Tissue = Dead Tissue

Eventually

3

Vitals Are Vital

- Blood Pressure
- Pulse
- **Respirations**
- **Oxygen Saturation**

- Also included in your Primary Survey
  - Level of Conciseness
  - Speech Pattern
  - Obvious Respiratory Noise
  - Patient Position

4

Respiratory Assessment

- Confusion, Agitation, Orientation
- Cyanosis (Blue) (*late sign*)
- Diaphoresis (sweaty/ clammy)
- Accessory Muscle Use (labored breaths)
- Jugular Venous Distention
- Nasal Flaring / Pursed Lip Breathing

Respiratory Arrest

- **Respiratory Arrest**
  - Respiratory arrest typically means that a patient's respirations are completely absent or inadequate to maintain oxygenation (pulse might be present)
  - Management of respiratory arrest includes the following interventions:
    - Give oxygen
    - Open the airway Provide basic ventilation
    - **Provide respiratory support with the use of artificial airways (OPA and NPA)**
    - Suction to maintain a clear airway
    - Maintain airway with advanced airways

- **Respiratory Distress**
  Oxygen via nasal cannula or mask

6

Ventilation & Oxygen During CPR

- During the first few minutes of witnessed cardiac arrest a MPIC should not interrupt chest compressions to put in an advanced airway.
- In other words, Advanced Airway placement in cardiac arrest should not delay initial CPR and defibrillation for VF cardiac arrest (Class I).

7

Bag-Mask Ventilation

- Bag-mask ventilation is a crucial airway management skill as taught in CPR
- Successful bag-mask ventilation depends on three things:
  - **Patent airway**
  - Adequate mask seal
  - Proper ventilation (volume, rate, and cadence).
- Airway patency is obtained using *airway maneuvers* and *adjuncts*.

8

Airway Adjuncts

- Once an open airway has been established, it must be maintained. Airway devices are important adjuncts in achieving this goal.
- Airway adjuncts will prevent the tongue from occluding the airway and provide an open conduit for air to pass.

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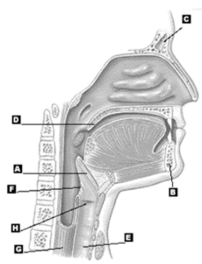
Upper Airway

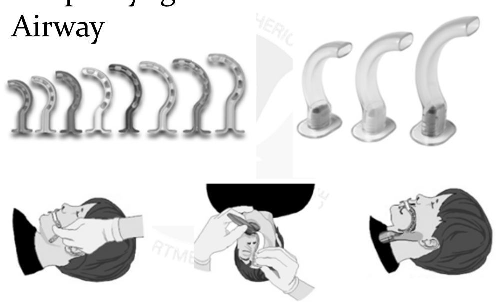


A	Epiglottis
B	Mandible
C	Frontal Sinus
D	Soft Palate
E	Trachea
F	Glottis
G	Esophagus
H	Vocal Cords

10

What Are My Options?

- Oropharyngeal Airway



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Oropharyngeal Airway (OPA)

- Oropharyngeal airways should be reserved for use in a deeply unconscious (unresponsive) patients with no cough or gag reflex.
- Incorrect insertion of an airway can displace the tongue into the hypopharynx, causing airway obstruction.
- The OPA must be removed if protective gag reflexes are present. Will likely induce vomiting and result in aspiration if not removed.

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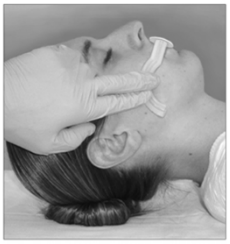
Oropharyngeal Airway Sizing



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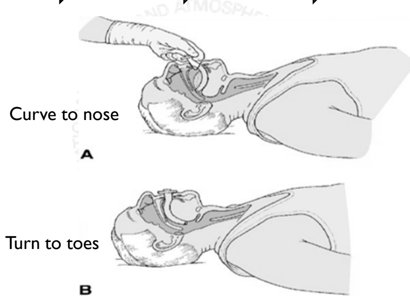
Insertion of Oropharyngeal Airway

Measure → A Insert → 180° Twist → B Insert



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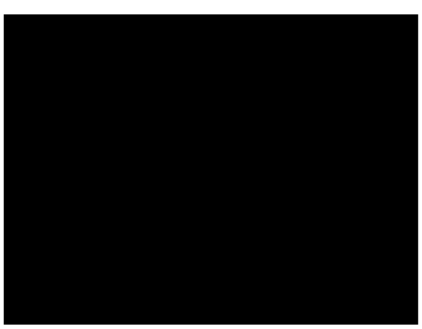
Oropharyngeal Video



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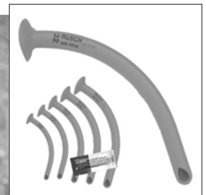
Other Options

- Nasopharyngeal Airway



Soft rubber or plastic hollow tube that is passed through the nose into the posterior pharynx.

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Nasopharyngeal Airways

- Nasopharyngeal airways are useful in patients with airway obstruction or those at risk for development of airway obstruction, particularly when conditions such as a clenched jaw prevent placement of an oral airway.
- Better tolerated than oral airways in patients who are not deeply unconscious.
- Airway bleeding can occur in up to 30% of patients following insertion of a nasopharyngeal airway.
- Seek medical advice before placing a nasopharyngeal airway in patients with severe craniofacial injury or basilar skull fractures due to <u>rare</u> but possible inadvertent intracranial placement.

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Nasopharyngeal Insertion

- Prior to insertion, the NPA should be coated with water-soluble lubricant or anesthetic jelly.
- The device is then inserted along the floor of the naris into the posterior pharynx behind the tongue.
- MPICs should note that the tube can be rotated slightly if resistance is encountered.

- More common potential hazards of using the NPA include:
  - Using an airway that is too long which may cause the tip to enter the esophagus, increasing gastric distention and decreasing ventilation during rescue efforts *.
  - Injury to the nasal mucosa causing bleeding which occurs in up to 30 percent of insertions and can lead to aspiration of blood or clots *.

* Stoneham MD. The nasopharyngeal airway. Assessment of position by fibreoptic laryngoscopy. Anaesthesia 1993; 48:575.

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EOA

- **Esophageal Obturator Airway (EOA)**
  - The EOA is a useful adjunct during cardiopulmonary resuscitation when endotracheal intubation is not feasible (J Schofferman; P Oill; A J Lewis CHEST.January 1976;69(1):67-71. doi:10.1378/chest.69.1.67)
  - This should never replace a more advanced airway if available (*JAMA* 1983;250:1081-1084)

19

i-gel

i-gel

i-gel

i-gel

i-gel

King LTS-D

Advantages of the King *continued*

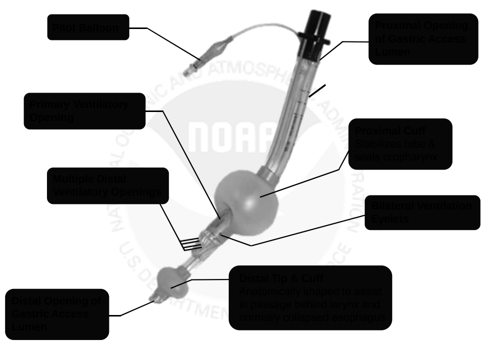
- Smaller than other devices (e.g., Combitube).
- More cost-effective than other options.
- Minimizes gastric insufflation.
- LTS-D enables passing of gastric tube into stomach.
- Comes in various sizes.

#3:	**4–5 feet**
#4:	**5–6 feet**
#5:	**Greater than 6 feet**

Disadvantages

- Patient must be unresponsive without a gag reflex.

Design of the King LTS-D



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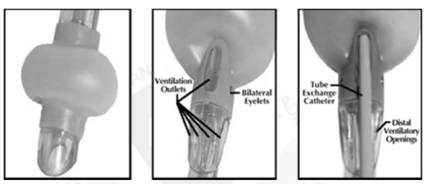
King LTS-D Design *continued…*



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Comparison of Tube Sizes

COLOR	Yellow	Red	Purple
SIZE	3	4	5
ITEM #	KLTD203	KLTD204	KLTD205
OD	14 mm	14 mm	14 mm
ID	10 mm	10 mm	10 mm
RECOMMENDED PATIENT SIZE	4-5 feet (122-155 cm) in height	5-6 feet (155-180 cm) in height	greater than 6 feet (180 cm) in height
CUFF PRESSURE	60-70 cmH_2O	60-70 cmH_2O	60-70 cmH_2O
MAXIMUM CUFF VOLUME	60 ml	80 ml	90 ml
	Range: 45–60 ml	Range: 60–80 ml	Range: 70–90 ml

Indications

- When tracheal intubation indicated, but unsuccessful or unavailable.
- Access to the patient is limited (e.g., trauma patients, entrapment, etc.).
- Difficult or emergent airways, in which other options may not be feasible.
- Cardiopulmonary arrest (optional).

Contraindications

- Presence of gag reflex.
- Caustic ingestion.
- Obstructed airway.
- Esophageal trauma or disease.

Same contraindications as the Combitube

Insertion Procedure

- Have all equipment ready prior to attempt.
- Test cuff inflation system for leaks.
- Apply a water-soluble lubricant to the *posterior* distal tip of the device.
- Hold KLTD/KLTSD in dominant hand at proximal connector.
- Use a superior (to patient's head) approach.
- Perform tongue-jaw lift while keeping head in a *neutral* position.
  - Head can be slightly extended or placed in the "sniffing" position if needed to facilitate placement.

Insertion Procedure *continued…*

- With the King LT (S)-D rotated laterally 45-90 degrees such that the blue orientation line is touching the corner of the mouth, introduce tip into mouth and advance behind base of the tongue.
- As the tube passes under the tongue, rotate the tube back to midline (blue orientation line faces chin).

Patient Insertion

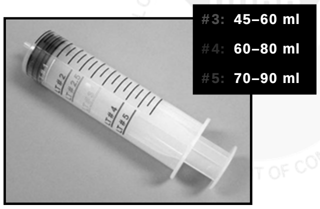
Insertion Procedure *continued…*

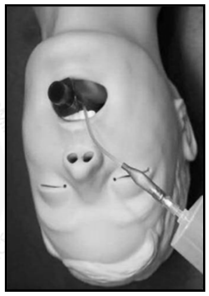
- Without excessive force, advance tube until connector is aligned with teeth and/or gums.

It is important that that the King is advanced all the way.

Insertion Procedure *continued…*

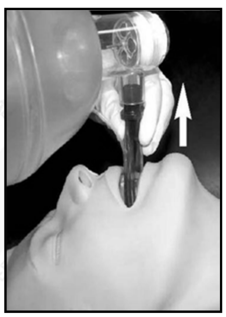
- Using a syringe, inflate the cuffs with the appropriate volume of air.
- Special (reusable) color-coded syringes can be utilized.





Insertion Procedure *continued…*

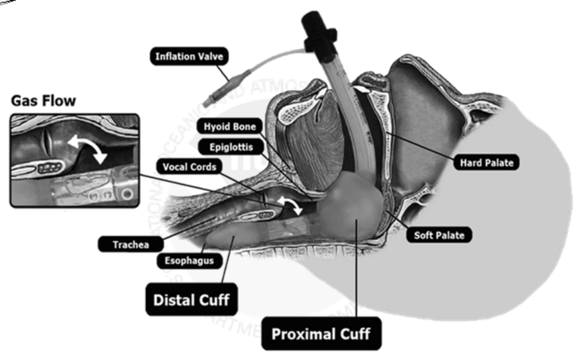
- Attach BVM to 15 mm connector.
- While ventilating, simultaneously withdraw until ventilation is easy and free-flowing.
  - There should be good tidal volume with minimal resistance.



Insertion Procedure *continued…*

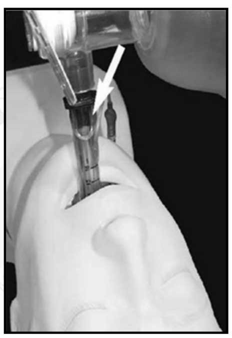
- Perform standard evaluation of lung sounds while ventilating through the King LT-D/LTS-D.
- Attach and utilize end-tidal CO_2 monitoring while the King LT-D/LTS-D is in place.
- Readjust cuff inflation as needed.
- Consider securing with tape or ET tube holder.
  - Securing with tape or ET tube holder not required, but recommended.
  - With cuffs inflated, King tends to fit snugly and securely.

Proper Position of the KLTD/KLTSD



The KLTSD Gastric Access Lumen

- Lubricate gastric tube prior to inserting into the gastric access lumen.
- Up to an 18 Fr catheter may be utilized.
- Attach suction unit to catheter.
- Once stomach contents are evacuated and suction no longer necessary, suction device may be detached.
- Catheter may left in place to "plug" lumen, and to continue to decompress the stomach.



Important Points & User Tips

- To avoid tracheal placement maintain head in a *neutral* position. Ventilation will not occur if placed in the trachea.
- If unable to ventilate, remove device and replace.
- If water soluble lubricant used, do not apply near ventilatory openings.
- Be prepared to re-inflate cuffs with another 10–15 cc in the event of air leakage (do not over-inflate).
- Insertion depth is critical, as the ventilatory openings must align with the laryngeal opening.

Important Points *continued…*

Be ***certain*** to advance the King LT-D/LTS-D until the base of the connector is aligned with the teeth and/or gums…

Failure to do so may result in a failed intubation attempt!

Return of Spontaneous Breathing

- If patient regains consciousness and respiratory drive, and is not tolerating the King, consider extubation.
  - Place them on their side and fully deflate cuffs.
  - Gently withdraw the tube.
  - Have suction ready and be prepared for vomiting.
- If patient regains respiratory drive, but remains unconscious but combative:
  - Consider sedation with midazolam and vecuronium.
  - Continue providing or assisting ventilations as necessary.

Spontaneous Breathing *continued…*

- During spontaneous breathing, the epiglottis or other tissue can be drawn into the ventilatory openings.
  - This can result in **obstruction.**
  - Advancing the King 1–2 cm normally eliminates this obstruction.

Key Points

- Limited oxygen supply results in damaged or dead tissue and is dependent on oxygen supply and duration of limitation
- SOB and fatigue often early symptoms of respiratory distress followed by Confusion, Agitation, and diminished Orientation
- Adjunct airways are a good way to secure an airway when used correctly

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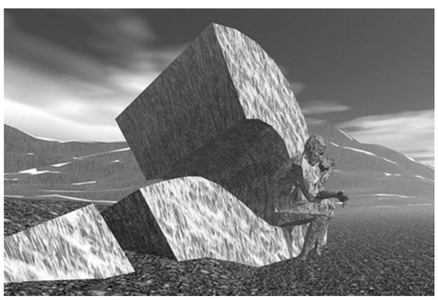
Questions?



Thermal Considerations for Diving

Special thanks to Dr. Neal Pollock for the content of this presentation

Contents

- Heat Exchange
- Thermoregulation
- Cold Stress
- Heat Stress
- Physiological Adaptations

Heat Exchange

Four major avenues:

- Radiation
- Conduction
- Evaporation
- Convection

Post-ice dive suit overpressure insulation; New Harbor, Antarctica

Major Avenues of Heat Exchange

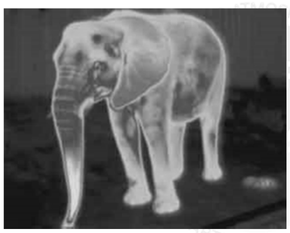
Radiation
- electromagnetic energy radiating from an object to any cooler object

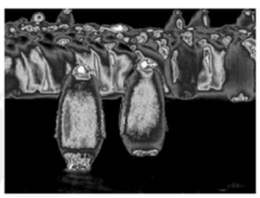
Conduction
- heat flow from an object in physical contact with any cooler object (generally most important in diving)

Evaporation
- heat energy expended to convert liquid water to gaseous state (e.g., evaporating sweat)

Convection
- heat flow mediated by circulating currents developing in any warming or cooling liquid or gas

Thermoregulation





Thermoregulatory Control

- **Hypothalamus**
  - the integrative thermostat for thermoregulation
  - cold response: posterior hypothalamus
  - heat response: anterior hypothalamus
- **Sensory Inputs**
  - peripheral receptors (primary): cutaneous (skin)
  - central receptors: spinal cord, abdomin
- **Effector Actions**
  - alter thermal conductivity: vasodilation/vasoconstriction
  - alter evaporative heat loss: sweat rate and pattern
  - alter metabolic heat production

Thermoregulatory Continuum

Body Heating

- Death (>43 C)
- Sweating Stops
- Sweating
- Vasodilation
- Hypothalamic Setpoint — **37±1 C**

Body Cooling

- Vasoconstriction
- Non-Shivering Thermogenesis
- Shivering
- Shivering Stops
- Death (<22^{+} C)

Cold Stress

Minimizing Thermal Loss

Radiation
- use of reflective barriers (with adequate insulation)

Conduction
- insulation is the inverse of conduction (units = 'clo')
- increase insulation (i.e., decrease thermal conductivity) of protective clothing

Evaporation
- respiratory losses are obligatorily high breathing dry air
- reduced if wicking layers transfer moisture away from skin or as microclimate humidity climbs

Convection
- maintenance of stable microclimate (i.e., minimize air flow)

Wind Chill

- Quantifies the heat transfer effect of moving air
  - wind chill temperature is the still air temp. with similar cooling to a given air temperature and wind combination
- Relevant to unprotected skin only

Standardized Cold Air Test (SCAT)
McMurdo Station, Antarctica, 1994:
90 min in 5 C and 0-10 knot wind

NWS Windchill Chart

Temperature (°F); Wind (mph)

Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

$$\text{Wind Chill } (^\circ F) = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Wind Chill Risk Categories

WCTI °F (C)	Description	Health Concern
32 to -23 (0 to -9)	Low	◆ Slight increase in discomfort
-23 to -31 (-10 to -24)	Moderate	◆ Uncomfortable ◆ Exposed skin feels cold ◆ Risk of hypothermia if outside for long periods without adequate protection
-32 to -42 (-25 to -44)	Cold	◆ Risk of skin freezing (frostbite) ◆ Risk of hypothermia if outside for long periods without adequate protection
-43 to -51 (-45 to -60)	Extreme	◆ Exposed skin may freeze in minutes ◆ Serious risk of hypothermia if outside for long periods
< -51 (< -60)	Very Extreme	**DANGER!** ◆ Outdoor conditions are hazardous ◆ Exposed skin may freeze in <2 min

Issued by Environment Canada (2001)

Case Report

- 34 yo male; numbness/paresthesia in left hand post-dive
  - dive: 90 fsw for 90 min, 6 C (43°F), drysuit, wrist cpu
    - trimix - 10% O_2, 50% He, 40% N_2
  - symptoms extended to mid-forearm and then evolved to waxing/waning burning sensation
- Differential: DCS?
- Non-freezing cold injury (NFCI; 'trench foot') typically associated with prolonged extremity immersion/wetness
  - threshold conditions will vary with overall stress
  - treated as for post-herpetic neuropathy (Amitriptyline)
    - improved at 6 weeks, still sensitive to vibration at 6 months

Cold Water Immersion

- Heat loss augmented by high heat capacity of water
  - ~3500 times greater than air
    - heat capacity = density * specific heat
- Water conducts heat away 20-27 times faster than air
- **Critical Water Temperature**
  - lowest temp. at which maximal vasoconstriction can maintain core temp. (i.e., without shivering) for 3 h
    - 32-35 C (90-95°F) for a semi-naked, resting subject
    - 29-33 C (84-91°F) for a lightly exercising subject
    - individual response affected by body size, mass-to-surface area ratio, subcutaneous fat thickness, hydration status

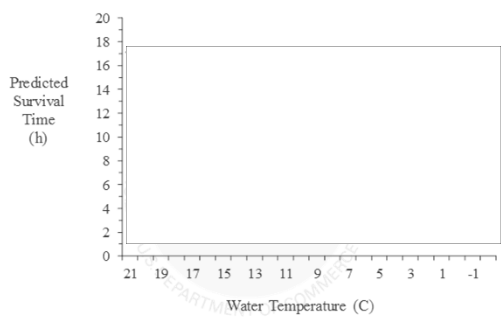
Cold Water Immersion

- Four phases of insult
  - 1. Initial immersion response (cold shock) - 0-2 min
    - ↑ heart rate, ↑ respiratory rate, ↑ blood pressure; ↓ cerebral blood flow velocity
    - more likely with water ≤15 C (59°F)
  - 2. Short term immersion (swimming failure)
    - crippling weakening occurs much faster than expected
  - 3. Long term immersion (hypothermia)
    - evolution varies
  - 4. Circum-rescue collapse
    - increased risk upon removal from water

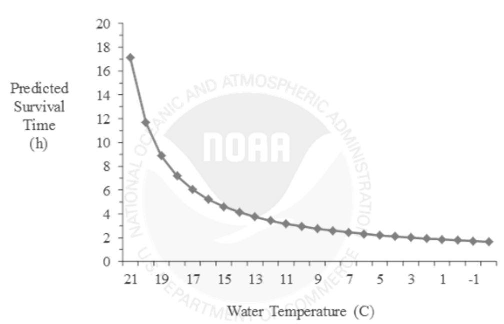
Swimming vs Holding Still

- Conductive heat loss increases
  - increased exposed surface area and peripheral circulation
- Convective heat loss increases
  - decreased stability of near-skin microclimate
- Metabolic heat production increases
  - muscular activity with possible reduction in shivering (thermogenesis)
- Switchpoint temperature for swimming vs. holding still?
  - ~24 C (75°F) - more heat loss with swimming below this temp.
- Survival:
  - dependent upon swim time and distance to safety
  - swimming failure will occur much faster than expected

Immersion Survival Time Prediction



Immersion Survival Time Prediction



Predicted survival time for lightly clothed immersed persons declines very quickly in water <23 C (73°F)

Survival Strategies

- Simple practices may prolong survival time if victims have sufficient buoyancy
- **HELP**
  - knees together and pulled up to chest (requires buoyancy)
    - heat escape lessening position
      - for self-protection
  - protects high heat loss areas of armpits, anterior chest, groin and thighs

RICHARD MELVIN ILLUSTRATION

- **Huddle**
  - group faces inward, wrap arms around adjacent individuals
  - primarily holds group together; might reduce heat loss a bit

'Afterdrop'

- A post-exposure decrease in core temperature often follows the end of cold exposure: 'Afterdrop'.
- Contributing mechanisms
  - attenuated shivering, thermogenesis
  - conductive heat loss along tissue thermal gradients
  - convective cooling via changes in peripheral blood flow
- 'Afterdrop' may increase and prolong the risk window for further physiological compromise

Slow-cooling Immersion

Temp (C)	Signs and Symptoms	
36	Sporadic shivering	
35.5	Gross shivering in bouts	
35	Uncontrollable shivering, mental confusion, decreased will to struggle, decreased motor activity (maximal voluntary exposure)	
34	Amnesia, poor articulation, motor degradation	
33	Hallucinations, clouded consciousness (50% mortality)	
32	Cardiac arrhythmias	Probably pessimistic for many acute cases
30	No response to pain	
29	Loss of consciousness	
28	Loss of pupillary reflex	
27	Ventricular fibrillation, death	

Cold Exposure Survival Profiles

- 8/26 survivors of serious cold exposure
  - core temp. at admission 23.6±2.4 C (74.5±4.3°F)
  - critical factor for survival was no evidence of asphyxia
- 19-year-old male recovered following 13 h of immersion to chin level in frozen creek water (in car)
  - core temperature of 22 C (71.6°F)
  - weak 12 beats·min^{-1} pulse lost upon removal from water
    - decrease in vasoconstrictive drive? (unlikely due to short time course and continued cold air exposure)
    - likely due to hypotension secondary to loss of hydrostatic pressure and handling stress
      - i.e., circum-rescue collapse

Cold Exposure Survival Profiles

- 29-year-old female fell while skiing down a frozen waterfall gully in Norway
  - wedged between rock and ice with space continually flooded with water
  - struggled for 40 min; removed after ~80 min
  - air evac to medical center – 230 min post-immersion
  - core temp. in OR 14.4 C (58°F), ↓ to 13.7 C (57°F)
  - full cardiopulmonary bypass restored cardiac rhythm (~15 min) and then core temp. (~170 min)
  - 5 month follow up found excellent mental function and improving residual partial pareses in limbs

Hypothermia Symptoms

MILD →	MODERATE →	SEVERE
T_c 35-32 C	T_c 32-28 C	T_c <28 C
• tachycardia	◆ increased incoord.	◆ decreased heart rate
• hyperventilation	◆ shivering slows	◆ not follow commands
• shivering	◆ confusion	◆ inability to walk
• introversion	◆ worsening stumbling	◆ loss of consciousness
• slow moving	◆ worsening mumbles	◆ depressed respiration
• poor coordination	◆ weakness	◆ no shivering
• poor concentration	◆ drowsiness	◆ dilated pupils
• uncomfortably cold	◆ hallucinations	◆ cyanotic
• fatigue	◆ amnesia	◆ decreased blood pressure
• hypertension	◆ cardiac dysrhythmias	◆ muscle rigidity
• peripheral pallor		◆ appearance of death

- Note: presentation may be much more idiosyncratic than implied here

Hypothermia Re-warming

Temp (C)	Category
35-32	**Mild** - can be re-warmed with a wide variety of simple, non-invasive techniques (e.g., heating blankets)
32-28	**Moderate** - requires aggressive management (e.g., forced air & airway warming, gastric & peritoneal lavage) - prepare for cardiac dysrhythmias
<28	**Severe (Deep)** - requires aggressive active core warming techniques (e.g., airway/IV fluid warming, body cavity lavage, cardiopulmonary bypass) - prepare for cardiac arrest

Effective Re-warming Techniques

- Passive re-warming is simple and effective for mild cases
  - shivering thermogenesis can increase resting metabolic rate fourfold
  - note: external insulation (e.g., blanket, dry clothes) will keep skin temperature low to prolong maximal shivering
- Exercise re-warming may produce a greater re-warming rate than shivering alone
  - unfortunately, exercise also produces a 1.5-3.0-fold greater afterdrop than shivering re-warming, effectively slowing core temperature restoration
- Forced air warming may not exceed shivering rewarming rate but it can reduce afterdrop

Ineffective Re-warming Techniques

While the alternatives may be limited in some situations, the following are not optimal re-warming strategies

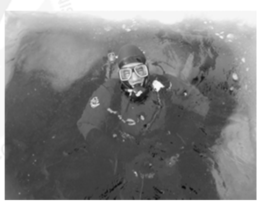
- Extremity immersion re-warming
  - thought to be an option to avoid afterdrop but studies have shown generally trivial re-warming capability
- Skin-to-skin heat donation
  - inadequate quantities of energy transferred, restricts freedom of movement of potential rescuer
- Warm fluid ingestion
  - inadequate quantities of energy transferred due to the small volumes that can be delivered

Re-warming Guidelines

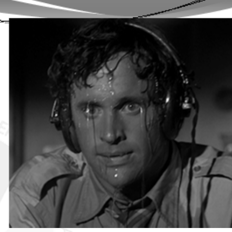
- Handle casualties carefully
  - anticipate actions that may prompt physiological collapse
    - rough handling
    - removal from water
    - transport in upright position
- Take steps to ensure that any treatment initiated can be sustained through successful conclusion

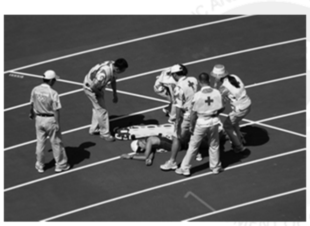
Thermal Protection in Cold Water

- Wet and Drysuits
- Hot water suits
- Helmets/FFM



Heat Stress





Heat Exposure Limits

- Core temperatures of 39 C or 40 C (102°F or 104°F) have been recommended as upper allowable limits
  - OSHA requires work modification intervention when oral temperature exceeds 37.6 C (99.7°F)
  - core temperatures of 42 C (108°F) have been reported during 56 km ultra-marathon running events
- Critical variables determining core temperature response
  - work rate
  - relative humidity

Heat Index

- Scale developed by U.S. National Weather Service to quantify heat transfer associated with relative humidity
  - Heat Index (HI) temperature or 'Apparent Temperature' is the dry air temperature with similar heat stress to a given air temperature and relative humidity (RH)
    - assumes standard conditions of shade and light wind
- E.g., 95°F (35 C) air temp + 55% RH = 110°F (43 C) HI

National Weather Service Heat Index Chart

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure and/or Strenuous Activity

■ Caution ■ Extreme Caution ■ Danger ■ Extreme Danger

Heat Index Risk and Disorders

HI °F (C)	Risk Category	Heat Disorders
80-<90 (27-<32)	Caution	• Fatigue possible with prolonged exposure and/or physical activity
90-<105 (32-<41)	Extreme Caution	• Sunstroke, heat cramps and heat exhaustion possible with prolonged exposure and/or physical activity
105-<130 (41-<54)	Danger	• Sunstroke, heat cramps or heat exhaustion likely; heatstroke possible with prolonged exposure and/or physical activity
>130 (>54)	Extreme Danger	• Heatstroke/Sunstroke highly likely with continued exposure

Issued by U.S. National Weather Service (1990)

Heat Illness Classification

- **Heat Edema**
  - peripheral edema
- **Heat Cramps**
  - muscle cramps and spasm
- **Heat Syncope**
  - temporary loss of consciousness
- **Heat Exhaustion**
  - fatigue, confusion, hypotension, nausea/vomiting (n/v), temporary syncope, paradoxical chills of head and neck
  - mental function fairly high and T_{core} <40 C (104°F)
- **Heat Stroke**
  - severe headache, pronounced mental status changes, fatigue, n/v, syncope, possible cessation of sweating
  - T_{core} ≥40 C (104°F)

Heat Illness Treatment

- **Heat Edema**
  - rest, elevate extremities
- **Heat Cramps**
  - stretch, ice massage, oral fluids (with electrolytes)
- **Heat Syncope**
  - rest, supine with feet elevated, monitor vital signs
- **Heat Exhaustion**
  - rest, active cool, ABCs, monitor core temp., oral fluids
- **Heat Stroke**
  - ABCs, urgent cool, monitor vitals/core temp., IV fluids

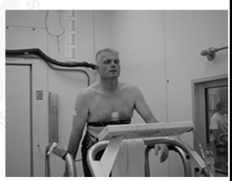
Physiological Adaptation

◆*Vulpes lagopus*

◆*Vulpes pusilla*

Heat Adaptation

- Heat adaptation easy to measure in both lab and field
  - i.e., threshold effective stress easily reached
- Substantial changes are observed with 5-10 days of exposure (intermittent or continuous)
- Primary adaptation is an increased work capacity
- Adaptations for any given submaximal workload include:
  - lower heart rate
  - higher sweat rate
  - hypotonic sweat (conserves salt)
  - delayed/reduced core temp. rise



ECU Environmental Chamber Heat Trial

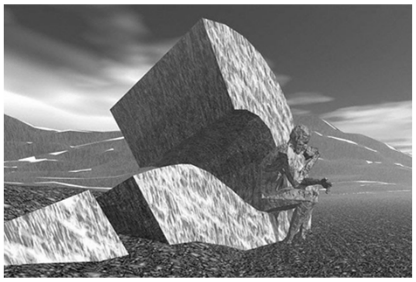
Cold Adaptation

- Cold adaptation is much more difficult to document than heat adaptation
- 1) a greater-than-threshold effective stress is hard to maintain
  - behavioral changes can more effectively protect the near-skin microclimate from cold exposure
    - e.g., additional clothing, physical activity, available shelter
  - subjective cold tolerance is typically less than heat tolerance
    - subsequently self-limiting exposure when possible
- 2) no simple test like physical work capacity
  - study of whole body and peripheral responses to cold stress are much less definitive

Cold Adaptation?

- Historically, effective stress threshold may have been lower due to conditions of nutrient intake restriction
- Dramatic cold adaptation could be a non-event with our current luxuries (nutrition and protective equipment)
  - Korean women divers prior to switch from cotton suits to wetsuits may have been last group affected

Questions?



Medications and Diving

Global View

- Drug vs. Diagnosis
- General Considerations
- Specific Drugs Actions

U.S. Food and Drug Administration
Protecting and Promoting *Your* Health

Drug:

- 1) Therapeutic agent; any substance, other than food, used in the prevention, diagnosis, alleviation, treatment, or cure of disease.
- 2) Medicinal substance: a natural or artificial substance given to treat of prevent disease or to lessen pain.

- Pharmaciuticals
- Naturopathic
- Herbal
- Recreational
- Prescription
- Over-the-counter

Physics of Diving and Drugs

- Increased partial pressure may alter pharmacokinetics
- Effects of hydrostatic pressure

4

The Effects

- Alteration in CNS function
- Change in cardiac function combined with effects of fluid shift related to diving.
- Changes in body dynamics/physiology

5

EFFECTS OF SMOKING

- Short-term effects:
  - CO poisoning
  - Neurologic changes
  - Sensory loss
  - Heart rhythm and rate changes
  - Increased blood pressure
  - Increased DCS risk from blood “clumping”

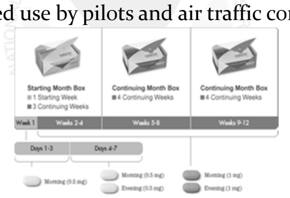
EFFECTS OF SMOKING

Smoking increases many of the risks of scuba diving

- Long-term effects:
  - Lung cancer
  - Obstructive lung disease
  - Heart problems
- Prevention:
  - Short term: Abstain at least several hours before diving
  - Long term: Stop smoking

Chantix (varenicline)

- U.S. Boxed Warning: Serious neuropsychiatric events have been reported with use
- U.S. Navy does not prohibit use, but recommends against use while diving.
- FAA banned use by pilots and air traffic controllers.



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Zyban (bupropion)

WARNING

Serious neuropsychiatric events, including but not limited to depression, suicidal ideation, suicide attempt, and completed suicide have been reported in patients taking ZYBAN for smoking cessation. Some cases may have been complicated by the symptoms of nicotine withdrawal in patients who stopped smoking. Depressed mood may be a symptom of nicotine withdrawal. Depression, rarely including suicidal ideation, has been reported in smokers undergoing a smoking cessation attempt without medication. However, some of these symptoms have occurred in patients taking ZYBAN who continued to smoke.

9

Diabetes

- 2005 UHMS/DAN Workshop Proceedings
- Acceptable in recreational diving.
- Perhaps not in commercial diving.
- Oral controlled vs. insulin dependent

10

Sulfonylureas

- Sulfonylureas are usually well tolerated.
- Hypoglycemia is the most common side effect and is more common with long-acting sulfonylureas

11

Beta Blockers

- Increased airway resistance
- Depression, fatigue
- Negative chronotropic effects
- Underlying medical condition

12

Pseudoephedrine

- Rebound effect
- Reverse block
- Oxygen toxicity
- Chills, confusion, impaired coordination, drowsiness, seizure

13

Afrin (oxymetazoline)

- Rebound nasal congestion with extended use.
- Not to be used for more than 3 days.

14

Alcohol

- Impaired judgment
- Decreased awareness
- Increased dehydration

15

Gabapentin

- CNS depression
- Dizziness
- Confusion – difficulty with logic problems

16

Lithium

- Blackout spells
- Confusion
- Dizziness
- Seizure
- Slowed intellectual functioning
- Increased effects with dehydration

17

Cocaine

- Cardiovascular effects
- Impaired judgment
- Seizure

18

Amphetamines

- Cardiac arrhythmias
- Lower seizure threshold
- Aggressive behaviors

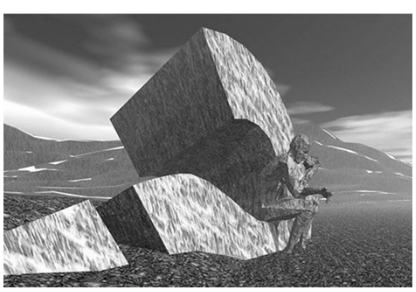
19

Tricyclic Antidepressants

- Consider medical reason for drug
- Side effects
  - Orthostatic hypotension
  - Cardiac electrical conduction disturbances
  - Lower seizure threshold
  - Sedation

20

Questions?



Hazardous Aquatic Life

Presented by the NOAA Diving Center
Seattle, Washington

Global View

- Animals that abrade or puncture
- Animals that sting
- Animals that bite
- Animals that shock
- Animals that are poisonous to eat
- Key Points

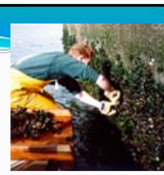
Introduction

- **Need & Value:** You will be diving in waters with potentially hazardous aquatic organisms. You will need to be able to recognize which ones are hazardous, how to avoid being injured by them, and know what to do if you are injured.

- **Effect:** You will become familiar with certain hazardous aquatic organisms and how to take appropriate actions to prevent injury. You will become familiar with the basic first aid measures to treat these injuries.

Animals that Abrade or Puncture

Abrade



- Mussels and Barnacles:
  - Invertebrate, sedentary filter feeders
  - Hard calcium shells with sharp brittle edges
  - Found in intertidal areas (+10 to -30 ft), on rocks, piers, vessel hulls and other hard substrates
- Hard Corals:
  - Found in tropical, subtropical waters from 0–150'.
  - Various hard/sharp exoskeleton designs.
  - Colonial, living portion of animal is a polyp

Balanus sp.

Abrade

- Signs and Symptoms
  - Pain, bleeding, swelling, tenderness
  - Infection, fever
- Complications
  - Foreign bodies in wound
  - Extreme risk of wound festering
    - Systemic infection

Acropora cervicornis
Staghorn Coral

Abrade

- First aid: All abrasions
  - Wash and clean affected areas
    - Betadine solution, antibacterial soap, flush with clean water
  - Control bleeding
  - Apply clean sterile dressings with topical antibiotic ointment
  - Antibiotics/tetanus
  - Keep area dry

Montastraea faviolata
Mountainous Star Coral

Puncture

- Segmented Worms
  - Polychaeta ('many' bristles')
    - Both free-living and sedentary
    - Very common in the marine environment
    - Fireworm (Hermodice carunculata)
      - Inhabit tropical waters, coral reefs
      - Predatory, carnivorous. Up to 1 ft in length
      - Sharp, venomous bristles along sides body
    - Bloodworm (Glycera dibranchiata)
      - Inhabit mud flats/intertidal all along coastal United States.
      - Prey upon worms, mollusks. Grow to over 1 ft in length
      - Four venomous jaws

Puncture

- Signs and Symptoms
  - Penetration by friable bristles on unprotected skin
    - Pain is immediate - burning or "pins & needles"
    - Inflammation, welts, numbness
  - Bitten
    - Bleeding, inflammation
    - Pain similar to a bee sting
- First Aid
  - Remove bristles with adhesive tape
    - Douse with vinegar or rubbing alcohol
  - Monitor for secondary infection
  - Clean wound/keep dry

Puncture

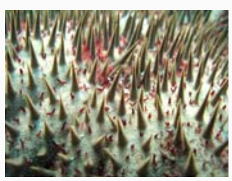
Strongylocentrotus purpuratus
Purple Sea Urchin

- Echinoderms ('rough skin')
  - Sea stars, Basket stars, Brittle stars Sea urchins, Sea cucumbers
  - All marine species, benthic dwelling
  - Worldwide distribution
- Sea urchins
  - Numerous species worldwide, very few are toxic (Flower Urchin)
  - Herbivorous
  - Sharp brittle spines made of calcium carbonate ($CaCO_3$)
    - Will penetrate hard sole boot
    - Are friable and may break-off
      - do not come out easily

Diadema sp.
Long Spine Sea Urchin

Puncture

- Sea stars
  - Crown of Thorns (*Acanthaster planci*)
    - Tropical oceans, Pacific
    - Predatory, feed on hard corals
    - 13-16 arms, up to 24 inches in diameter
    - Spines to 3 inches in length
      - Are friable and may break-off
      - Venomous



Puncture

Anarrhichthys ocellatus
Wolf Eel

- Signs and Symptoms
  - Embedded spines, skin discoloration
  - Immediate pain, inflammation, swelling, tenderness, redness, burning, "pins and needles", welts

Puncture

- First Aid
  - Soak for 30-90 min in non-scalding water (105°)
    - Heat labile toxin
  - Soak in mild acid to help break up/dissolve spines
  - Wash and clean affected areas
    - Betadine solution
  - Remove foreign bodies/objects
  - Apply clean dressings with topical antibiotic
  - Monitor for secondary infection
  - X-Ray to confirm foreign body in soft tissue
  - Spines may need to be surgically removed

Puncture

- Venomous Fish
  - ~1200 known venomous fish
  - All have either venomous dorsal, caudal, and/or pectoral spines
  - Stonefish Family
    - Numerous species
    - Sedentary, excellent camouflage
    - Venomous dorsal spines.
    - Tropical coastal regions: Indo-pacific, Florida/Caribbean
      - Indo-pacific: some species are deadly - requires anti-venom

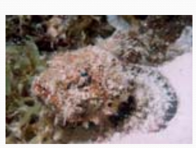
Lionfish Dorsal Spines

Scynanceia verrucosa.
Reef Stonefish

Puncture

- Scorpionfish Family:
  - Lionfish
    - Nine species, tropical (Indo-pacific)
    - Exotic/invasive in Caribbean
    - Very ornamental, slow moving
    - Also called Turkeyfish, Zebrafish.
    - Envenomation occurs through fin spines puncturing skin
  - Scorpionfish
    - Numerous species
    - Widespread tropical and temperate - most Indo/pacific
    - Several spines found on dorsal, pectoral, caudal/anal fins

Pterois volitans
Red Lionfish



Taenianotus triacanthus
Leaf Scorpionfish

Puncture

- Other Venomous Fish
  - Catfish (~3100 species)
    - Fresh and salt water , worldwide
    - 3 retro-pointed serrated spines at pectoral and dorsal fins
  - Dogfish and Ratfish
    - Chondrichthyes, temperate waters
    - Dorsal fin spines, powerful jaws
  - Surgeonfish
    - Circum-tropical
    - Blade-like spines, near tail

Ictalurus furcatus
Blue Catfish

Hydrolagus colliei
Spotted Ratfish

Acanthurus chirurgus
Doctorfish

Puncture

- Signs and Symptoms
  - Severe localized pain
  - Swelling and redness
  - Nausea and vomiting
  - Shock, fainting
  - Paralysis
  - Cardiac and respiratory distress

Puncture

- First Aid
  - Monitor patient LOC/ABC
  - Wash/remove foreign bodies
  - Place injured area in hot, non-scalding water (105°) for 30-90 min (Heat labile toxin). Test water temp with other limb
  - If conditions worsen, seek medical help
    - Anti-venom for stone fish
    - Antibiotics/tetanus

Puncture

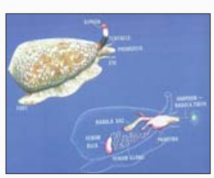
Urobatis halleri
Round Stingray

- Stingrays
  - Flat, round, or diamond shaped
  - Burrow in sandy bottoms to await prey
  - Most have detachable retro-serrated barb on tail
  - Injuries occur when handled, provoked, stepped on
    - Tail whips up and makes a slashing cut
    - Venom is injected, barb may remain embedded
  - Can be avoided: shuffling feet
  - Estimated 1500 accidents/yr in U.S.

Puncture

- Signs and Symptoms
  - Severe localized pain
  - Swelling, redness, bleeding, tissue damage
  - Sweating, shock, fainting, rapid/irregular heartbeat
- First Aid
  - Monitor LOC/ABC
  - Control bleeding, clean wound
  - Seek medical attention
    - removal of barb
    - tetanus

Puncture



- Cone shells (*Conus* spp)
  - Tropical mollusk
  - ~600 different species
    - All are venomous
    - Some species venom is lethal
  - Highly developed modified tooth - harpoon used to seize prey
  - Do not handle or attempt to collect
  - Neurotoxin interferes with neuromuscular transmission (25% human mortality)

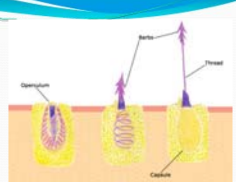
Puncture

- Signs and symptoms
  - Acute inflammation at puncture site
  - None to moderate pain
  - General numbness and tingling
  - Muscle paralysis
  - Respiratory failure
- First Aid
  - Pain management
  - Monitor LOC/ABC : possible respiratory/ cardiac arrest
  - Pressure immobilization - cover wound/puncture mark(s)
  - Transport to advanced medical care

Humans have killed themselves by handling cone shells

Animals that Sting

Stings



- Cnidaria (Cnid - greek for nettle)
  - Hydrozoa: hydroids
  - Scyphozoa: true jellies
  - Anthozoa: corals, anemones
  - Two phase life cycle: polyp and medusa
  - All have stinging cells called cnidoblasts. Inside cell is a nematocyst:
    - 17 different types in 3 groups: whiplike, glutinate, penetrant
      - Pressure sensitive trigger
      - Venom consists of inflammatory chemicals and enzymes
      - Extent of injury depends on species and amount injected

Stings

- Hydrozoans
  - Portuguese Man o' War (*Physalia* spp.)
    - Two species - Atlantic and Pacific
    - Not a true jelly - colony of 3-4 different types of polyps
    - Circumtropical, drift with wind & tide
    - Float to 6 in, tentacles averaging 30 ft
    - Blooms of juvenile organisms
    - Responsible for the bulk of cnidarian en-venomations

Stings

- Hydrozoans
  - Fire Coral (*Millepora alcicornis*)
    - Found in depths less than 50 ft
    - Tropical/Sub-tropical worldwide
    - Encrusting - grows over existing corals, rocks…any hard structure
    - Orange, yellow-green, or brown skeleton with white ends/tips
    - Stings may take several days to resolve
    - Lacerations have dermo-necrotic effects.

Stings

- Hydrozoans
  - Hydroids
    - Small, feathery branched colonies
    - Filter feeders. Food source for nudibranchs
    - Thousands of species
      - 200+ identified in Alaska
    - Benthic, shallows to > 130'
    - Global distribution
    - Small pieces/feathers fragmented by storms

Aglaophenia struthionides
Ostrich-plume Hydroid

Stings

- Anthozoans
  - Anemones
    - Essentially a giant polyp, feeds on plankton and small fish
    - Sedentary on hard substrates
    - Sting usually not serious
  - Corals
    - Polyp secretes are $CaCO_3$ skeleton around itself
    - Found worldwide, feed on plankton, small crustaceans, and worms
    - Sting negligible

Condylactus gigantea
Purple-tipped Anemone

Montastrea cavernosa
Boulder Star Coral Polyps

Stings

- Scyphozoans
  - Jellies
    - Gelatinous bell shaped animals with stinging tentacles
    - Several thousand species worldwide (tropics to temperate)
    - ~200 species capable of stinging humans
    - Certain species capable of swimming
    - Can get large - 5 ft dia bell, tentacle to 100 ft (Lion's mane)
    - Usually cause mild skin irritation

Thysanostoma sp.
'Pelagic' Jelly

Aurelia aurita
Moon Jelly

Stings

- Jellies (Con't.)
  - Sea Wasp (Box Jellies)
    - Warm, coastal waters worldwide
    - Bell size ranges from inches to over 1 foot
    - Can actively swim!
    - Most lethal jelly, one of the most potent venoms known.
      - Fatal en-venomations have occurred, Australia & Indo-Pacific
      - Certain species can kill adult within three minutes (*Chironex fleckerii*).

Humans have died from Box jelly stings

Carybdea branchi
S. African Box Jelly

Stings

- Signs and Symptoms
  - Can range from mild discomfort to agony
    - depends on individual, species of organism, and extent of stings
  - Throbbing, blistering, redness, immediate pain, muscle cramps, nausea, respiratory distress, shock, paralysis, convulsions, death
  - Hyper-pigmentation of skin. Scarring from severe stings
  - Fragmented tentacles remain 'active'
  - Clothing is effective in preventing stings

Stings

- First Aid
  - Douse area with vinegar (5% acetic acid)
    - neutralizes toxin & inactivates remaining nematocysts
    - does not relieve pain
  - Leave blisters intact. Keep wound dry, clean and aerated
  - Remove remaining tentacles
    - avoid rubbing or use of fresh water or alcohol
  - Apply cold packs to reduce swelling/pain
  - Box Jellies: (in addition to above)
    - Keep patient calm and quiet
    - Wrap with pressure bandages
    - Assess ABC's and LOC, seek medical help
    - Administer anti-venom

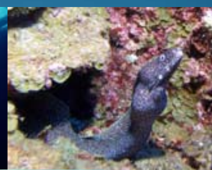
Contact Dermatitis

- Sponges (Porifera)
  - Sedentary filter feeders
  - Siliceous spicules and toxins
    - Touch-Me-Not and Fire sponges
    - Burning, itching, redness, swelling
- Sea Cucumbers
  - Asian delicacy, over fishing
  - Holothurin
    - Released by certain species as defense. Neurotoxin to kill would be predators
    - Dermatitis and blindness risk if eaten

Neofibularia nolitangere
Touch-me-not Sponge

Actinopyga agassizii
Five-toothed Sea Cucumber

Animals that Bite




Bite

- Blue-Ringed Octopuses (*Hapaloclaena* spp)
  - Secretive, small octopus with bright blue rings or spots.
    - Observed when disturbed, hunting, or mating
  - Tropical: Japan to Australia, Indo-pacific
  - Not aggressive, en-venomations extremely rare
    - Handling of aquarium specimens
  - Bacteria in salivary glands produce the neurotoxin (tetrodotoxin) - dart frogs, newts, pufferfish, cone snails
  - Painless to 'bee sting' bite

Humans have killed themselves handling these animals

Bite

- Signs and Symptoms
  - Onset w/in minutes
  - General numbness/tingling
    - lips and tongue
  - Excessive salivation
  - Dysphagia
  - Dysarthria
  - Sweating, dizziness
  - Headache
  - Muscle paralysis
  - Tremors
  - Respiratory failure
- First Aid
  - No anti-venom
  - Clean and treat puncture wound
  - Pressure immobilization
  - Monitor LOC/ABC : possible respiratory/ cardiac arrest
  - Seeks advanced medical care.

Bite

- Venomous Aquatic Reptiles

  - Freshwater snakes
    - Cottonmouth (Water Moccasin)
      - *Agkistrodon piscivorus*
        - related to the Copperhead, *A. contortrix*
      - Gulf Coast, United States.
      - Excellent swimmers, abundant.
      - Edible, as are all snakes.

Bite

- Saltwater snakes
  - Sea Snake/Kraits
    - Tropical Pacific/Indian oceans near shore/pelagic
    - ~62 species
    - Various colors, patterns
    - Generally mild-tempered
    - Very potent venom
      - respiratory paralysis (20x as toxic as Cobra venom)
      - Small fangs
        - Typically reluctant to bite

Aipysurus laevis
Olive-brown Sea Snake

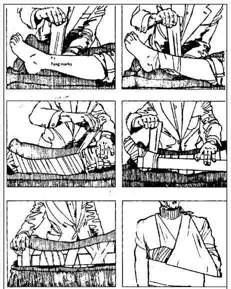
Lauticauda colubrina
Yellow-lipped (Banded) Sea Snake

Bite

- Prevention
  - Be familiar with potential snake habitat
  - Make your presence known
  - Avoid and respect snakes, do not handle
- Signs and Symptoms
  - Copperhead
    - Swelling, bruising at site
    - Chills, nausea, vomiting, sweating
  - Sea snakes:
    - Headache, thirst, sweating, vomiting, muscle aches, Rhabdomyolysis, paralysis
    - 30 - several hours after bite

Bite

- First Aid
  - Pressure immobilization
  - Assess level of consciousness
  - Monitor ABC's
  - Seek medical help and transport ASAP
  - Administer anti-venom
  - CPR/ Artificial Respiration



Pressure bandage immobilization technique. Courtesy of Commonwealth Serum Laboratories, Melbourne

Bite

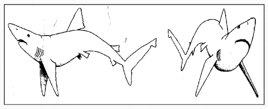
- Crocodilians:
  - Alligators
    - Only two species
      - American (*Alligator mississippiensis*) and Chinese (*A. sinensis*)
    - Fresh and brackish water
    - Blunt, square skull/nose
  - Crocodiles
    - 14 Species
      - Africa, Australia, Americas, Asia
    - Salt, fresh, and brackish water
    - Thinner, pointy skull/nose

Bite

- Fishes
  - Sharks (Chondrichthyes)
    - Close to 440 species. Only ~35 known to have injured humans
    - Several species known to attack unprovoked:
      - White, Bull, Mako, Tiger, Hammerhead, Oceanic Whitetip
    - Range in size from inches to ~40 ft,
    - Jaw strength, bite mechanics
    - Most only attack when provoked
    - Prior to attack some species display specific behaviors

Cetorhinus maximus
Basking Shark

Bite



"C'mon, c'mon! You two quit circling the table and just sit down!"

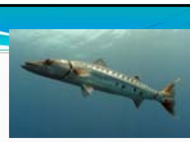
- Shark Behavior
  - Physical, chemical stimuli
  - Bumping
  - Position of pectoral fins, radius of watch circle
  - Feeding frenzy
  - Bite and spit - traumatic hemorrhaging subdues prey
  - Territorial
  - Defensive bite

Bite

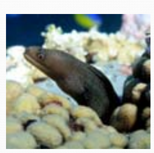
Carcharhinus longimanus
Oceanic White-tip

- Shark Bite Prevention
  - Avoid large shark habitat
  - Avoid diving at dusk and dark
  - Use safety divers
    - constantly monitoring sharks
    - equipped with defensive weapons
  - Exit water when uncomfortable or if behavior changes
    - May appear once a vessel has stopped
  - Do not carry dead fish
  - Using terrain for protection

Bite



- Great Barracuda (*Sphyraena barracuda*)
  - Large predatory fish (4-5 ft), silver in color
  - Found in tropical and sub tropical coastal waters
  - Many sharp canine-like teeth which produce a cutting wound
  - Known to follow divers



- Moray eels (*Gymnothorax spp*)
  - Predators found in reefs crevices
  - Tropical and sub tropical coastal waters
  - Ominous appearance: branchial pumping
  - Strong jaws and sharp teeth, poor eyesight

Bite

- Hazards
  - Barracuda
    - More likely to attack by mistake in reduced visibility - In limited visibility enter slowly do not splash
    - More likely to attack shiny objects, lights or speared fish
  - Moray eels
    - Divers bit when sticking in recesses
    - Will defend themselves harassed

Bite

- Marine Mammals
  - Seals and sea lions
    - Rarely dangerous unless threatened
    - Very aggressive during mating at rookeries
    - Have bitten/killed humans
- Hazards
  - Stay clear of rookeries, do not harass aggressive male animals
  - Extremely strong, fast, and agile.
  - Be respectful of these animals.

Hydrurga leptonix
Leopard Seal

Eumetopias jubatus
Stellar Seal Lion

Bite

- First Aid for all biting injuries
  - Control bleeding
    - keep victim still, calm
  - Monitor ABC's, treat for shock
  - Clean and dress wound, allow drainage (infection risk)
  - Seek medical help as needed

Moray Eel bite

Shark Bite

Animals that Shock

Shock

- Electric Rays
  - 69 species, Marine
  - Shallow coasts to 3500 feet
  - 8 - 220 volts
    - not likely to kill an adult
  - Used to stun prey

Torpedo californica
Pacific Electric Ray

Shock

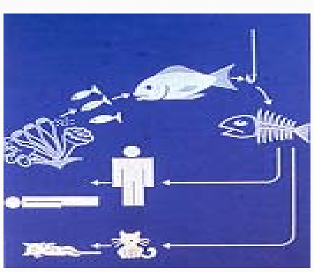
- Electric Eel
  - *Electrophorus electricus*
  - S. America: Amazon and Orinoco Rivers
  - Up to 600 volts
    - not likely to kill an adult
  - 6 feet in length, 40-45 lbs
  - Used to stun prey, defense, and communication

Shock

- Northern Stargazer
  - *Astroscopus guttatus*
  - Marine, Eastern U.S.
  - Depths shallow to ~120'
  - Benthic, ambush predator
  - Up to 2' in length
  - Gland behind eye produces shock
  - Used for defense

Animals that are Poisonous to Eat

The Cat Test



Ciguatera

- 'Tropical Fish Poisoning'
  - Ciguatoxin: produced by a photosynthetic dinoflagellate: *Gambierdiscus toxicus*
  - 800 species of fish have been known to carry the toxin
    - Bioaccumulation
    - Large, top predators usually affected: Barracuda, Jacks, Hogfish, Eels, Groupers, Wrasses
  - Rarely affects pelagic species: tuna, marlin, dorado
  - As many as 50,000 people/year become ill
  - Fish must be tested to determine if poisonous
    - Cooking does not make fish safe
    - Freshness has no bearing

Ciguatera

- Symptoms:
  - Onset w/in 2-6 hours
  - Gastrointestinal
    - Metallic taste
    - Nausea/Vomiting/Diarrhea
    - Muscle pain, aches, abdominal pain
  - Neurological
    - Numbness/tingling of lips, tongue, throat
    - Paradoxical sensory disturbances
    - Visual Disturbances
    - Muscle Paralysis
    - Convulsions
    - Heart Failure
- First Aid:
  - No definitive cure
  - Induce vomiting w/in 4 hrs of eating
  - Seek immediate medical help
  - Recovery may take several years

Humans have died from Ciguatera poisoning: 12% mortality rate

Scombroid

- Species belonging to the Family Scombridae
  - Tuna, mackerel, bonito, bluefish
- Fish has been poorly refrigerated/stored or exposed to sunlight
  - develops a toxic histamine
  - fish may be normal in color, taste
- Account for up to 40% seafood illnesses
- Symptoms develop within few minutes and may persists for several days
- Histamine is heat stable

Thunnus thynnus
Bluefin Tuna

Scombroid

- Symptoms:
  - Onset from minutes up to two hours
  - Nausea/Vomiting
  - Diarrhea/Abdominal Pain
  - Headache, dizziness
  - Skin Flushing/Red Welts
  - Sweating
  - Itching
  - Respiratory distress
  - Cardiac palpitations
  - Shock
- First Aid:
  - Induce vomiting
  - Oral antihistamines
  - Seek advanced medical treatment
  - Typically resolves w/in 24 hours

Scomber scombrus
Atlantic Mackerel

Hallucinatory Fish Poisoning

- Primarily in the Pacific Ocean
  - Mullet/goatfish families
- Symptoms
  - Dizziness, loss of coordination, mental depression, hallucinations, nightmares
- Not fatal, typically resolves within 24 hours.

Pseudupeneus maculatus
Spotted Goatfish

Paralytic Shellfish Poisoning

- Caused by the dinoflagellate: *Protogonyaulax* spp.
- Occurs in mollusks on both the east and west coast of the United States
  - mussels, clams, oysters, scallops
  - may remain toxic for weeks to years
- Mollusks filter the plankton during ‘blooms’ accumulating levels poisonous to humans

Venerupus philippinarum
Manila Clams

Paralytic Shellfish Poisoning

- Symptoms:
  - May occur minutes after ingestion
  - Gastrointestinal
    - Nausea/vomiting/diarrhea
    - Abdominal cramps
  - Neurological
    - Tingling/burning sensation of lips, mouth, face
    - Numbness
    - Muscle weakness
    - SOB, slurred speech
    - Loss of consciousness
    - Respiratory failure
- First Aid:
  - Quickly induce vomiting
  - Seek advanced medical attention immediately
  - Be prepared to provide CPR

Mytilus trossulus
Bay Mussels

Pufferfish Poisoning

- Pufferfish from the Genus *Takifugu*. ~25 species
- Contain toxin found in skin, ovaries, intestine, and liver: Tetrodotoxin
  - Extremely potent. Deaths have occurred within minutes.
  - Mortality rate as high as 60%
- "Fugu" - considered a delicacy in Japan

Takifugu xanthopterus
Yellowfin Pufferfish

Takifugu ruprides
Tiger Pufferfish

Pufferfish Poisoning

- Symptoms:
  - Onset within minutes
  - Dizziness
  - Lack of coordination
  - Numbness in hands/feet
  - Paralysis begins in throat, arms, and legs.
    - Progresses through muscles in body
  - Respiratory distress/failure due to paralysis
- First Aid:
  - No known antidote
  - Induce vomiting.
  - Stand by to perform CPR, artificial respiration.
  - Transport to advanced medical care.

Key Points

- Be aware and recognize hazardous marine life in vicinity
- Prevent injuries. If you or your buddy do become injured - know treatment
- Treat injuries/wounds immediately
- Use copious amounts of vinegar to neutralize nematocyst toxins (Jellies)
- Use hot, non-scalding water to treat heat labile toxins (i.e. Rays, urchins, and fish)
- Humans have died from Sea Wasps, Cone shells, Blue Ringed Octopus, Sea Snakes, and Food Poisoning.

Professional Affairs

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

1

Recertification Requirements

- Actively working within an EMS system or patient care facility using your EMT skills
- Complete recert requirments
- Demonstrate continued cognitive competency
- Submit completed application prior to March 31 of the year your cert expires

2

Cognitive Competency Options

- Continuing Education Option
  - 72 hours of education including
    - CECBEMS approved 24 hour EMT refresher course
    - 48 hours of additional EMS related CE
    - Maintain skills as verified by your training program director, director of operations, or physician medical director
    - Current CPR certification at the appropriate level

3

Cognitive Competency Options

- Exam Option
  - Take and pass the exam between October 1 and March 31 of the year your certification expires
  - One attempt only

4

What is CECBEMS?

- Continuing Education Coordinating Board for Emergency Medical Services

5

EMT Refresher Options

- Traditional
  - Complete a State or CECBEMS 24 hour EMT refresher course
- Continuing Education – Must include:
  - Preparatory 1 hr
  - Airway 2 hrs
  - OB, Infants, Children 2 hrs
  - Pt Assessment 3 hrs
  - Medical/Behavioral 4 hrs
  - Trauma 4 hrs
  - Elective 8 hrs

6

Additional EMS related CE – 48 hrs

- A maximum number of 24 hours can be applied from any one topic area
- Hour for hour credit can be applied for standardized courses (including, but not limited to, ABLS, ACLS, AMLS, EMPACT, EPC, PHTLS, PALS, PEPP, etc.)

7

Additional EMS related CE – 48 hrs

- A maximum number of 12 hours can be applied from each of the following courses: Teaching CPR - Emergency Driving - Dispatch Training
- A maximum number of 24 hours can be applied from Distributive Education towards this section and must be State or CECBEMS approved

8

Additional EMS related CE – 48 hrs

- College Courses
  - Hour for hour credit can be applied for college courses that relate to your role as an EMS professional (1 college credit = 8 CEU). For example, but not limited to anatomy, physiology, biology, chemistry, pharmacology, psychology, sociology, statistics, etc.

9

Additional EMS related CE – 48 hrs

Hours from the following courses can be applied hour for hour with no maximum:

- Advanced Trauma Life Support
- EMS Course Instruction
- Wilderness EMS Training.

10

Additional EMS related CE – 48 hrs

Courses that Cannot be applied:

Clinical Rotations, CPR, Emergency Medical Responder Course, home study programs, instructor courses, management/leadership courses, performance of duty, preceptor hours, serving as a skill examination, and volunteer time with agencies.

11

DMT Recertification Requirements

- Provide medical "fitness to undergo compression" (fitness to dive) certificate
- Provide documentation showing Emergency Medicine Training
- Provide evidence of 24 CEU's related to emergency-related training/education.
- Provide evidence of 24 hours of diving medicine/other emergency related experience.
- Provide a completed Diver Medic Certification or Recertification form (download at NBDHMT.org)

12

DMT Recertification Requirements

- Send all of the above to the NBDHMT headquarters with your payment in the amount of $75.00, payable to NBDHMT

13

Breakdown of CEUs

- At least 4 hours specifically in diving medicine taught by a NBDHMT approved instructor
- At east 16 hours general emergency medicine at the EMT level or higher
- 4 remaining hours elective from either of the above categories

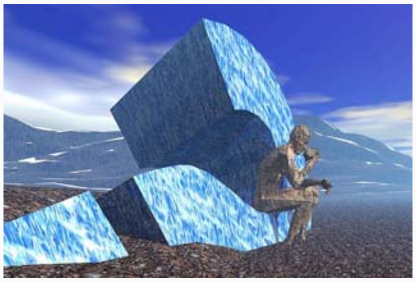
14

Websites

- National Board of Diving & Hyperbaric Medical Technology
  - http://www.nbdhmt.org/index.asp
- National Registry of Emergency Medical Technicians
  - https://www.nremt.org/nremt/about/nremt_news.asp
- Other

15

Questions?



Dive Computers
History, Theory, and Operation

Nick Jeremiah
NOAA Diving Center
Seattle Washington

Overview

- Dive Computer History
- Dive Computers Today
- Dive Computer Theory
- Dive Tables and Computers
- Dive Computers: Good and Bad
- Dive Computer Data
- Summary

Origins of Dive Computers

- Tethered, surface supplied, hard-hat deep divers spend their dive at one depth
- Surface tenders responsible for computing and executing decompression requirements
- Introduction of SCUBA in the 1940's allows divers to become mobile
- SCUBA divers are without surface contact, thus responsible for own decompression
- Need for a diver carried decompression device recognized

Origins of Dive Computers

- 1951 - Navy forms a committee for Undersea Warfare and Underwater Swimmers
- 1953 - Committee issues report on controlling DCS in free swimming divers (Groves and Monk, 1953)
  - Offers a preliminary design for diver-carried decompression device
- 1953 - ONR project at SIO sponsors a theoretical design for an analog computer
- Prototype design sent to the Foxboro Co. for manufacture

Foxboro Decomputer Mark 1

- Two tissue pneumatic device
- 1955 - computer presented to NEDU for testing
  - Testing indicated method practicable but refinement needed to increase accuracy and consistency
- Not widely used
- 1956 - NEDU reinforces need for small, diver carried apparatus to indicate proper decompression on ascent

SOS Decompression Meter

- Introduced 1959, Italian Manufacturer
  - Commercially successful, manufactured into the 1990's
  - One tissue (compartment), pneumatic device
  - AKA: The 'Bend-o-Matic'

TRACOR Computer

- Introduced 1963, Developed by Texas Research Associates
  - Electric, analog
  - Designed to simulate nitrogen diffusion throughout the body
  - NEDU tested showed device to be unreliable

GE Decompression Meter

- Introduced 1973
  - Used semi-permeable membranes and a four-chamber mechanism representing four tissue groups
  - Initial testing showed promise but never brought to market

Farallon Decomputer

- Introduced 1975
  - Used four permeable membranes representing two theoretical tissue groups - one fast, one slow
  - Mechanical: simulated nitrogen absorption rather than calculating
  - Considered unreliable

Dacor Dive Computer - DDC

- Introduced 1978, Dacor Corp. of Illinois
- Prototype electronic dive computer
  - Never mass produced due to complications in acquiring chips
- High energy consumption
  - Special batteries hard to find

DCIEM Digital Deco Computers

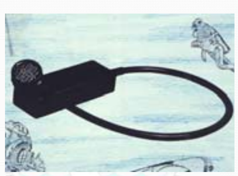
XDC - 1

- Introduced 1970's, Defence and Civil Institute of Environmental Medicine (DCIEM) - Ontario Canada
- Surface based desktop computers
  - Real-time computer controlled diving

XDC - 2

DCIEM Digital Deco Computers

- Introduced ~1979
- First 'diving computer'
  - Calculates absorption in real time
- Several hundred sold in early 80's
- XDC - 4 developed for mixed gas diving, never made it to market



XDC - 3 (Cyberdiver)

- Diving computers originated with mechanical and electrical analog devices – transitioning to computers

Dive Computer Revolution - 1983

- Orca EDGE : Haldanean Model w/ 12 compartments
- DecoBrain I: Swiss Table based multi-level decompression device
  - The first truly successful, commercially available dive computers

- 1983 saw collaborative effort between Oceanic and US Divers
  - $1.5 million dollar R & D project
  - Resulted in Oceanic Data Master and US Divers Data Scan
  - Integrated both a no deco. computer and an air consumption computer

Dive Computers Today

- Through the late 1980's and 1990's, advances in affordable, low power, electronic microprocessors and the advent of reliable low cost, temperature stable pressure transducers, allowed electronic dive computer innovation and design to explode.
- As of 2012, over 80 different designs available
  - Late 1980's, less than ten

What Dive Computers Do

- With an increase in pressure, calculates theoretical nitrogen uptake (in-gassing) and, with a decrease in pressure, nitrogen release (out-gassing)
- Calculations based on pre-programmed, mathematical models (algorithms)
- Primary variables used in calculations: depth and time
- Secondary variables: Ascent rate, water temp, breathing gas, profile sequence
- As depth (pressure) changes during a dive, device continually computes decompression status
- Displays decompression status to diver

What Dive Computers Do Not Do

- Take into consideration:
  - Individual body type/metabolism
  - Level of hydration
  - Physical fitness
  - Body fat content
  - Blood circulation
  - Injuries restricting circulation
  - Medications, drugs
  - Body temperature
  - Level of exertion
  - PFO
  - Mental status
  - Gender

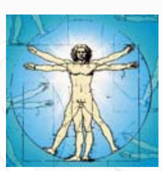
Dive Computer Advertisements

"This calculation model takes into account dissolved as well as gaseous nitrogen formation (microbubbles) in the Venous and Arterial blood supply and tissue groups relative to ascent rate, decompression, etc."

"The model employed is 'adaptive' because it factors in human physiological changes that can affect time versus Saturation / Desaturation, during diving: Work output, body temperature, etc."

Dive Computer Theory

- Nitrogen Tension:
  - The amount of nitrogen present in tissues
  - Measured in units of pressure (fswa)
  - Nitrogen tension at sea level is 26.07 fswa
- Body Tissues:
  - Fast up-take/release: blood and organs
  - Slow up-take/release: fat and bone
  - Intermediate tissues in between
  - Density and blood flow
- Compartments:
  - Tissues are placed into compartments to approximate their rate of nitrogen up-take/release
  - Differentiate when talking about the body or the theoretical model



Dive Computer Theory

- Half-times:
  - Theoretical value assigned to a compartment
  - Time for any given compartment to fill or empty 50%: to become half saturated
  - Tissues are considered saturated after 6 half-times (98.5%)
- USN Dive Tables are based on a model using six compartments with a range of 5-120 minute half-times
  - 720 minutes (12 hours) for the slowest tissue to become saturated or to have completely off gased
- Other tables (NAUI) use 240 minutes (24 hours) to represent the slowest tissue half-time
- Some suggest slow tissues should use 480 minutes.

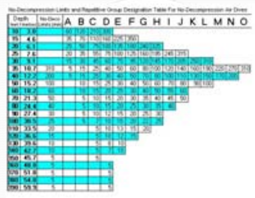
Dive Computer Theory

- M-Values:
  - The maximum nitrogen tension a tissue can tolerate at a given depth (M_n), without bubbles being produced during a continuous ascent.
  - Measured in units of pressure (fswa)
  - Specific M-values are calculated for each compartment
  - Intent of a no-deco dive is to surface without compartments reaching and exceeding their M_o value, thereby avoiding potential bubble growth.
    - dive time limits, slow ascents, safety stops
  - Ceiling: the depth a diver can ascend without nitrogen pressures violating the compartment M-value: M_{50}, M_{20}, M_{15}
  - Most computers use M-values more conservative than the USN model.
  - These values are proprietary information

Dive Computer Theory

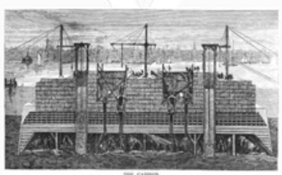
- Primary difference in dive computers are the models types/number of compartments, half times, and M_o values.
- Model (algorithm) names:
  - Haldane, Buhlmann, Thalmann, Lewis, Powell-Rogers, Nikkola, Kidd-Stubbs
  - Buhlmann ZHL-12, ZHL-16DD, ZH-L8 (ADT), (MB), (PMG)
  - Mares-Weinke RGBM
  - Varying Permeability Model (VPM)
  - Variable Gradient Model (VGM)
  - Haldanean Model w/ RGBM, 8, 9, 10, 16, 20 compartments.
- Number of Compartments: up to 20
- Length of Half-times: 1 - 720 minutes
- M_o - Values: one per compartment

Comparing Computers with Tables



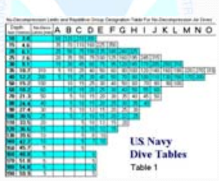
Dive Tables

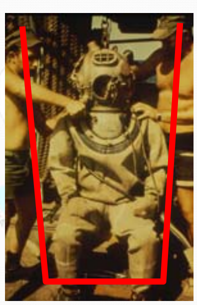
- Englishman John Scott Haldane, et al. 1906-1908.
- Developed in response to bridge/tunnel workers becoming injured.
- Experimental testing on goats
- Table with five compartments with half times of 5, 10, 20, 40, 75 minutes
- Adopted by USN: 1915
- Modified by USN: 1930's
- USN tables published: 1937
- USN tables modified: 1957



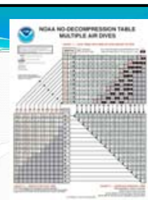
Dive Tables

- Square profile diving
  - Suited USN and commercial diving operations.





Dive Tables



- Used by recreational community: NAUI, SSI, YMCA, PADI…
- Square profile diving, not well suited for actual dive profiles
- Penalized by max depth assumption

Table Based Multi-Level Diving

No-Decompression Limits and Repetitive Group Designation Table For No-Decompression Air Dives

Depth feet	Depth metres	No-Deco Limits (min)	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
10	3.0		60	120	210	300											
15	4.6		35	70	110	160	225	350									
20	6.1		25	50	75	100	135	180	240	325							
25	7.6		20	35	55	75	100	125	160	195	245	315					
30	9.1		15	30	45	60	75	95	120	145	170	205	250	310			
35	10.7	310	5	15	25	40	50	60	80	100	120	140	160	190	220	270	310
40	12.2	200	5	15	25	30	40	50	70	80	100	110	130	150	170	200	
50	15.2	100		10	15	25	30	40	50	60	70	80	90	100			
60	18.2	60		10	15	20	25	30	40	50	55	60					
70	21.3	50		5	10	15	20	30	35	40	45	50					
80	24.4	40		5	10	15	20	25	30	35	40						
90	27.4	30		5	10	12	15	20	25	30							
100	30.5	25		5	7	10	15	20	22	25							
110	33.5	20			5	10	13	15	20								
120	36.6	15			5	10	12	15									
130	39.6	10			5	8	10										
140	42.7	10			5	7	10										
150	45.7	5			5												
160	48.8	5				5											
170	51.8	5				5											
180	54.8	5				5											
190	59.9	5				5											

U.S. Navy Dive Tables

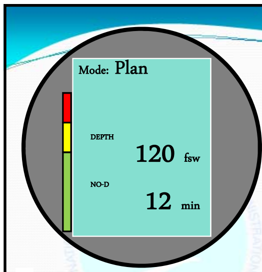
Table 1

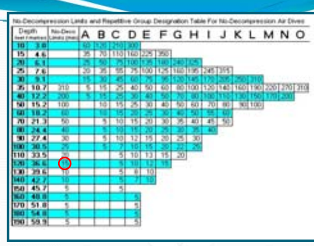
Table Based Multi-Level Diving

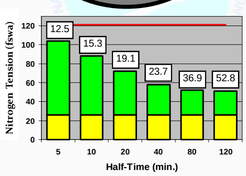
- Table MLD based (in general) on only one compartment of the underlying decompression model
- Added complications in dive planning and execution
- Solution: Model Computation Method
  - Use models, not tables, to calculate acceptable multi-level dive profiles

Multi-Level Diving On-The-Fly Computations

- At each step in the profile calculate the status of the decompression model
- Many tedious calculations…
- Dive Computers!





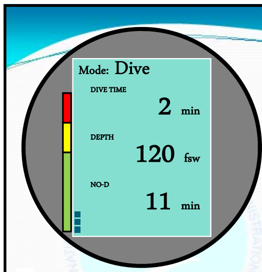


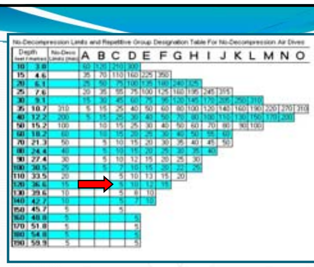
Dive Computer:

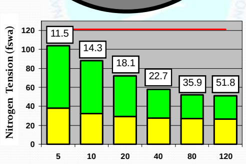
- Scrolling No-D Time for 120 fsw is 12 min.
- Controlled by 5-min. compartment

Decompression Table:

- Maximum No-D Bottom Time for 120 fsw is 15 min.
- Controlled by 5-min. compartment





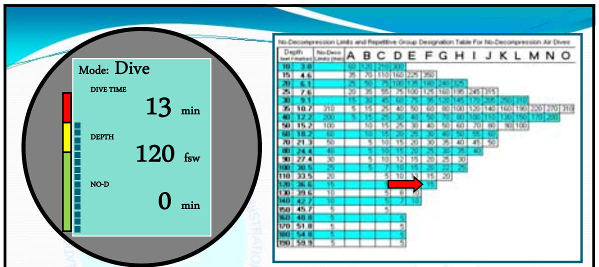


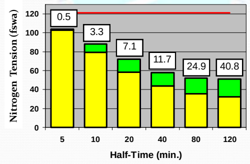
Dive Computer:

- Compartments building up pressure
- 11 minutes No-D time remains
- Controlled by 5-min. compartment

Decompression Table:

- 13 minutes No-D time remaining
- Controlled by 5-min. compartment



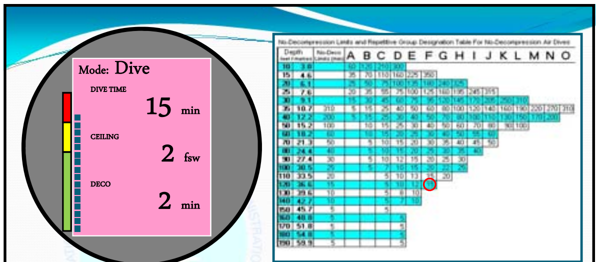


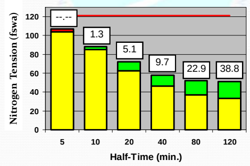
Dive Computer:

- Compartments still building pressure
- 5-min. compartment almost at limit

Decompression Table:

- 2 minutes No-D time remaining
- Controlled by 5-min. compartment



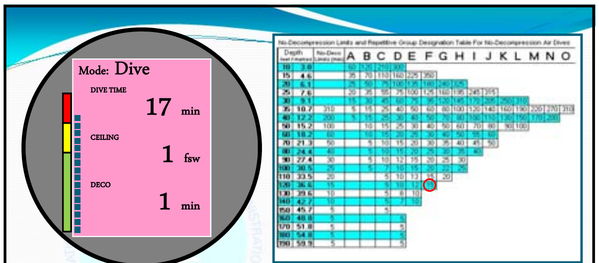


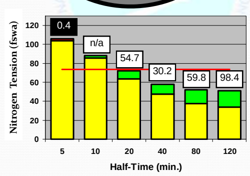
Dive Computer:

- 5-min. compartment over limit
- Ceiling: 2 fsw – Deco Time: 2 min.

Decompression Table:

- End of allowable No-D Time
- Start ascent to the surface at 30 fsw/min.



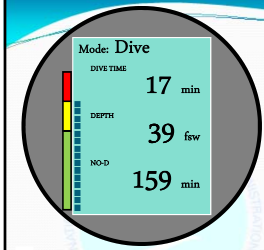


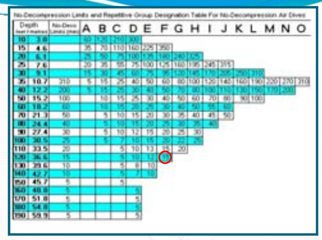
Dive Computer:

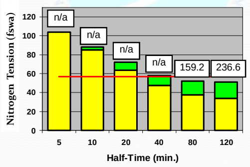
- At 60 fsw on ascent
- 5-min. compartment still over limit
- Ceiling: 1 fsw – Deco Time: 1 min.

Decompression Table:

- 2 minute into ascent at 30 fsw/min.
- No more No-D Time remaining

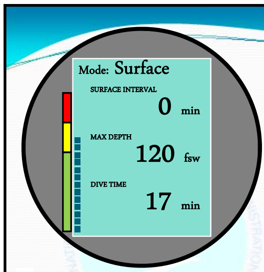


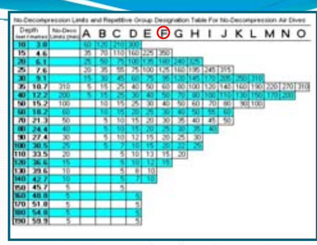


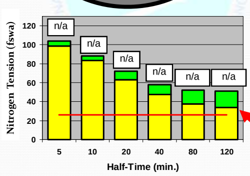


Dive Computer:
- 2-2/3 minutes into ascent
- 5-min. compartment below limit
- 159 minutes No-D Time – Controlled by 80-min. compartment

Decompression Table:
- 2-2/3 minutes into ascent
- No more No-D time remaining

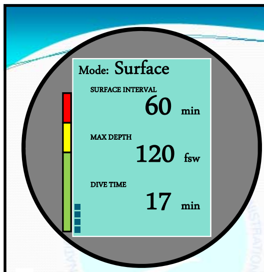


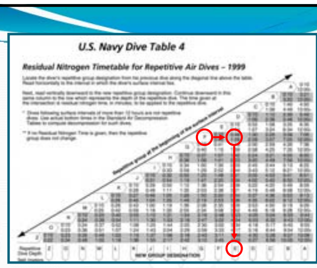


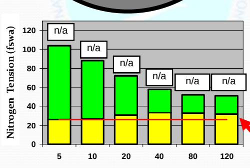


Dive Computer:
- End of dive
- All compartments below limit
- All compartments off-gassing

Decompression Table:
- End of Dive Repetitive Group = F
- "F" amount of nitrogen in 120-min. compartment of model

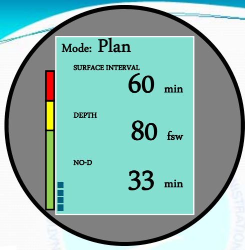


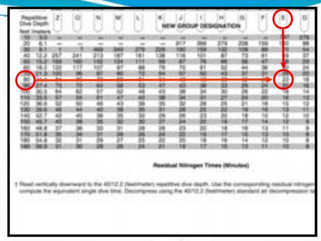


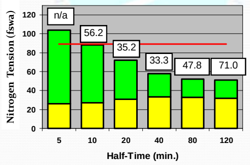


Dive Computer:
- 1 hour after end of dive
- 5 & 10-min. compartments almost back to surface pressure

Decompression Table:
- F drops to E between 0:46 & 1:29 Surface Interval
- "E" amount of nitrogen in 120 min. compartment of model





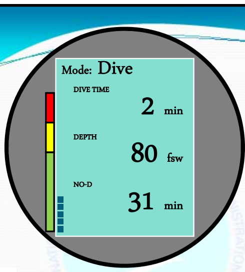


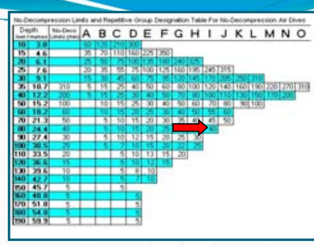
Dive Computer:

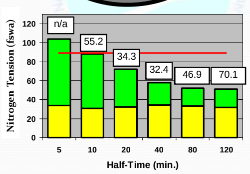
- No-D Limit at 80 fsw = 33 min.
- Controlled by 40-min. compartment

Decompression Table:

- RNT for Group E at 80 fsw = 23 min.
- Adjusted No-D limit at 80 fsw = 40 min. – 23 min. = 17 min.
- Based on 120-min. compartment





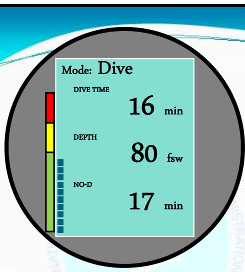


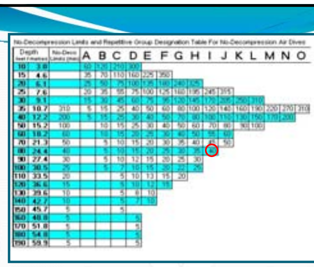
Dive Computer:

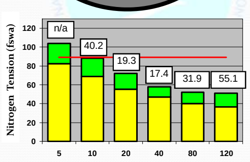
- Compartments building up pressure
- 31 minutes No-D time remains
- Controlled by 40-min. compartment

Decompression Table:

- 15 minutes No-D time remaining
- Based on 120-min. compartment





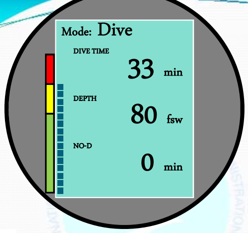


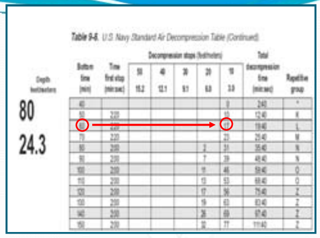
Dive Computer:

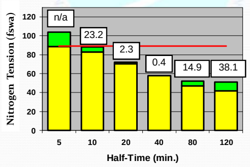
- Compartments building up pressure
- 17 minutes No-D time remains
- Controlled by 40-min. compartment

Decompression Table:

- End of allowable No-D Time
- Start ascent to the surface at 30 fsw/min. or go into Decompression







Dive Computer:

- **Compartments building up pressure**
- **40-min. compartment at limit**

Decompression Table:

- **Equivalent Bottom Time = 57 min.**
- **80 fsw for 60 min. Deco Table requires a 17 min. stop at 10 fsw**
- **End of dive RGD will be L**

Pro's and Con's

Advantages

- No Max Depth / Entire Bottom Time Rule
- Uses Actual Depth of Dive (51 vs. 60 fsw)
- Integrates Dive Profile
- Entire Model Used to Calculate MLDs
- Computational Reliability
- Accurate Depth Readings (±1-2 fsw)
- Ascent Rate Warnings
- Dive Profile Recording

Disadvantages

- No Max Depth / Entire Bottom Time Rule
- Uses Actual Depth of Dive (51 vs. 60 fsw)
- Integrates Dive Profile
- If Computer pushed to Limit – Model Pushed to Limit (Model Testing?)
- Mechanical/Electrical Failure
- Diver Needs to Understand the Limitations of the Computer
- Possible Crutch…breeding dumb divers

Algorithm Variability

Time allowed @ 100 fsw (30 msw). No-Stop Limits

- 19 min.
  - Oceanic Versa / Aeris Atmos
  - NiTek 1 (0) / Sherwood Wisdom
  - Zeagle Status (0)
- 17 min.
  - Suunto Solution (A0)
  - Suunto Vytek (P0/A0)
  - Cochran Commander +
- 16 min.
  - Dacor Darwin (P0)
  - Cressi Archimede (SF0)
  - UWATEC Aladin Sport
  - Seac Sub Aqualab
  - TUSA IQ-600
- 14 min.
  - Suunto Solution (A1)
  - Suunto Vytek (P0/A1 or P1/A0)
  - Cressi Archimede (SF1)
- 13 min.
  - Dacor Darwin (P1)
- 12 min.
  - NiTek 1 (1) / Zeagle Status (1)
- 11 min.
  - Suunto Solution (A2)
  - Suunto Vytek (P0/A2, P1/A1, or P2/A0)
  - Dacor Darwin (P2)
- 9 min.
  - Suunto Vytek (P1/A2 or P2/A1)
  - Dacor Darwin (P3)
- 7 min.
  - Suunto Vytek (P2/A2)

Abuse of Dive Computers

- Pushing dive computers to their no-deco limits
- Exceeding model and/or tested no-deco limits
- Blindly trusting the dive computer
- Exceed dive computer operational limits
- Taking out the battery to clear residual nitrogen
- Continuing to dive with a computer which did not turn on for the first dive
- Switching computers during a day of diving
- "Hanging" computer to clear warnings and prevent "freeze-up"

Incidence of DCS

- "Over the last two decades, electronic dive computers have replaced decompression tables in most segments of recreational diving. Yet during the same time, the overall incidence of decompression sickness (DCS) does not appear to have changed, dispelling early worries that abandoning tables to dive with computers would result in increased DCS.
  - Petar Denoble, Alert Diver, Summer 2010

Incidence of DCS

- "There is no evidence that multilevel dives with dive computers are more risky than square dives when they follow the same algorithm. The risk of DCS in no-decompression recreational and scientific diving is no greater now than when tables were prevalent. This is largely because dive computers are not pushed to the limits of their decompression models or algorithms."
  - Michael A. Lang, D.Phil. Alert Diver, Winter 2013

Computers as Sources of Data

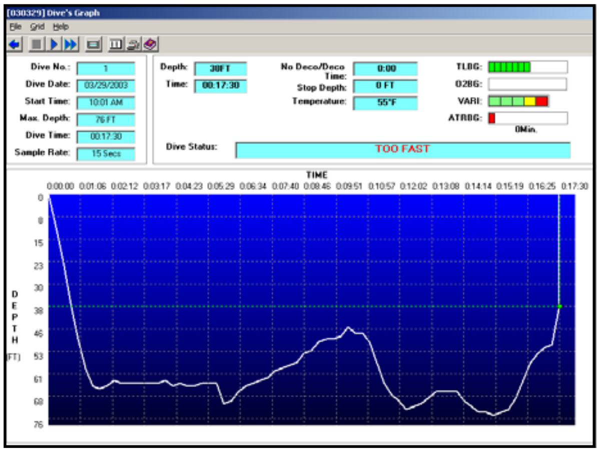
- Depths:
  - Maximum/Average
- Times:
  - Dive/Surface/Start & End
- Warnings:
  - Ascent/Deco/Deco Violation/Low Air
- Decompression Status:
  - End of Dive Loading/Maximum Loading/Minimum No-D Time/Omitted Deco Time
- Temperatures:
  - Max / Min
- Tank Pressures:
  - Start of Dive/End of Dive/SAC Rate
- Dive Profiles:
  - Downloader required for most

Why Obtain This Information?

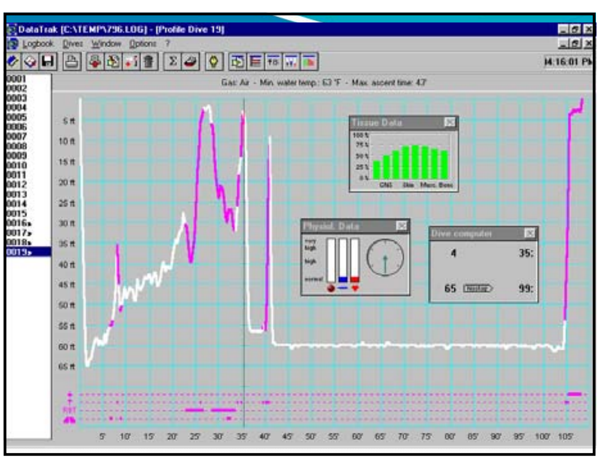
- Assist with treatment decisions
  - Compare with diver's recollection (cognitive symptoms?)
- For larger database to determine common safety issues
- For accident investigations
  - Assist law enforcement with fatalities
  - Lessons learned

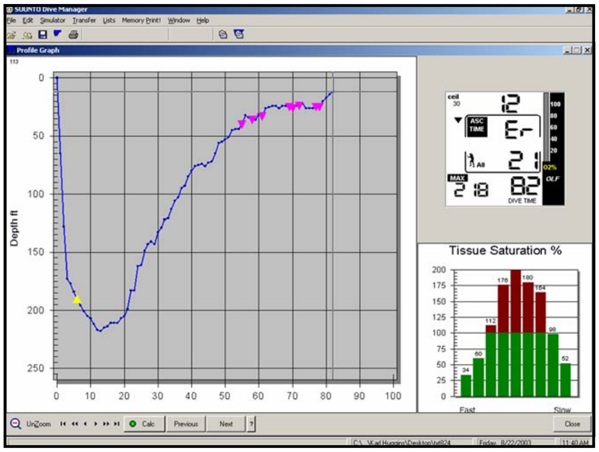
Dive Computer Interrogation

- Was the dive computer worn by the diver?
- Was it worn on all the dives done by the diver?
- Is the date and time set properly (offset)?
- Was it set for the gases used on the dive?
- How does it record dive profiles?
- What information can be obtained & how?
  - Patient, buddy, chamber staff, or instructor familiar with computer's data capabilities
  - Dive computer manuals: online/hard copy
  - Necessary hardware/software for downloading


[030329] Dive's Graph
File Grid Help
Dive No.: 1
Dive Date: 03/29/2003
Start Time: 10:01 AM
Max. Depth: 76 FT
Dive Time: 00:17:30
Sample Rate: 15 Secs
Depth: 38FT
Time: 00:17:30
No Deco/Deco Time: 0:00
Stop Depth: 0 FT
Temperature: 55°F
TLBG:
O2BG:
VARI:
ATRBG:
0Min.
Dive Status:
TOO FAST
TIME
DEPTH (FT)

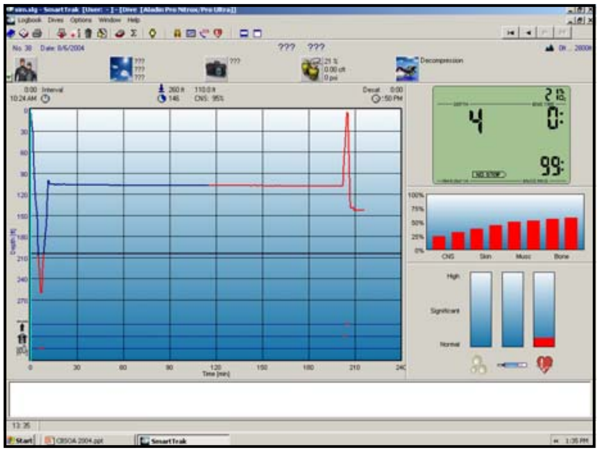

] - [Profile Dive 16]
Logbook Dives Window Options ?
Gas: Air - Min. water temp.: 64 °F - Air cons.: 0.83 cft/min (max. 1.22) - Max. ascent time: 8'
Tissue Data
Dive computer
Physiol. Data


DataTrak [C:\TEMP\796.LOG] - [Profile Dive 19]
Logbook Dives Window Options ?
Gas: Air - Min. water temp.: 63 °F - Max. ascent time: 47'
Tissue Data
Physiol. Data
Dive computer



Case Study: Diver in Respiratory Arrest - Initial Report

- 52 yr. old Female
- Missing for 2 hours – Possible maximum depth of 150 fsw
- 1350 hours: recovered from 70-90 fsw
  - Spat up bloody fluid - CPR initiated
- 1441 hours: weak pulse reported by USCG Rescue Swimmer
- 1454 hours: USCG Helo arrives at Chamber
  - Patient asystole, "vomiting" fluid, poor lung sounds (concern for pneumo), lower lip bitten through (seizure?)
  - No gear (dropped during rescue and was on the bottom)
- 1510 hours: CCTT 3 & 6A initiated w/compressions & ventilations
- 1546 hours: pronounced dead, 36 min. into treatment
- Two weeks later, gear recovered and computer downloaded

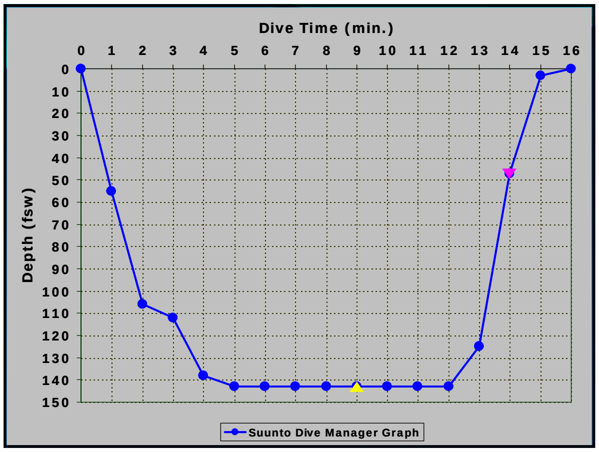


Case Study: Diver in Full Arrest: Initial Report

- 30 yr. old Female, full arrest
- Panicked while descending at 40 fsw
- Less than 5 minutes of dive time

Interviews

- Victim's Buddy stated that victim started getting shaky at about 80 fsw and they started towards the surface
- Buddy's dive computer showed ~110 fsw for 2 min.
- Divemaster stated he entered the water, saw small stream of bubbles and found victim laying on bottom at about 140 fsw with regulator out of her mouth
- Divemaster brought victim directly to surface, removed her gear (which floated), got victim into boat where CPR was started
- Gear (still floating) was pulled from the water shortly after victim was placed on the boat



Summary

- Dive computers came about due to a need for an effective multi-level, diver carried decompression device
- Use mathematical models to calculate theoretical nitrogen in/out gassing
- Do not monitor actual nitrogen uptake/release
- Do not consider individual physiology
- Many allow algorithm adjustments
  - Selection tends to be based on the features and functions desired
- They can provide valuable post-dive information

Questions?