Analyzing & Interpreting Arterial Blood Gases

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This Presentation is AARC Approved for 1.5 CRCE Credit Hours

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Learning Objectives

- Describe collection methods for an arterial blood gas
- Discuss avoidance strategies for pre-analytical errors
- List the process steps for ABG analysis
- Discuss the causes of metabolic acidosis & alkalosis
- Discuss the causes of respiratory acidosis & alkalosis
- Identify the role of ABG analysis with mechanical ventilation

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Collecting an ABG

Roche v-TAC

Software application to calculate arterial blood gas values from venous blood

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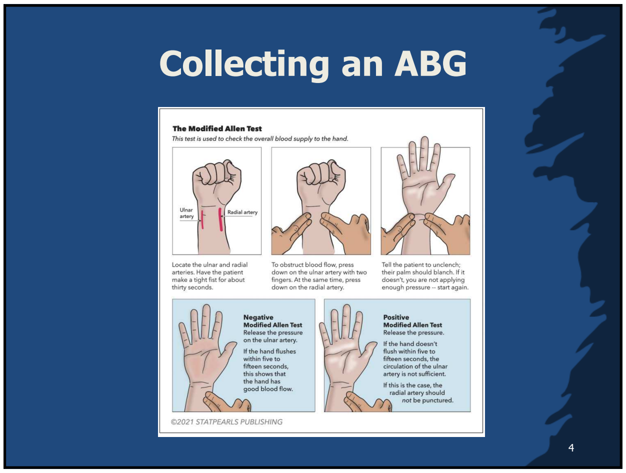
Collecting an ABG
The Modified Allen Test
This test is used to check the overall blood supply to the hand.
Ulnar artery
Radial artery
Locate the ulnar and radial arteries. Have the patient make a tight fist for about thirty seconds.
To obstruct blood flow, press down on the ulnar artery with two fingers. At the same time, press down on the radial artery.
Tell the patient to unclench; their palm should blanch. If it doesn't, you are not applying enough pressure -- start again.
Negative Modified Allen Test
Release the pressure on the ulnar artery.
If the hand flushes within five to fifteen seconds, this shows that the hand has good blood flow.
Positive Modified Allen Test
Release the pressure.
If the hand doesn't flush within five to fifteen seconds, the circulation of the ulnar artery is not sufficient.
If this is the case, the radial artery should not be punctured.
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Collecting an ABG
5

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Collecting an ABG
SPECIMEN
BIOHAZARD
PELIGROSO
Freeze
Refrigerate
Room Temperature
6

6

Influencing Factors

- Room air
- Leukocytes
- Hypo/hyperthermic

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ABG Analyzers (i-Stat)

8

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ABG Analyzers (ABL 800)

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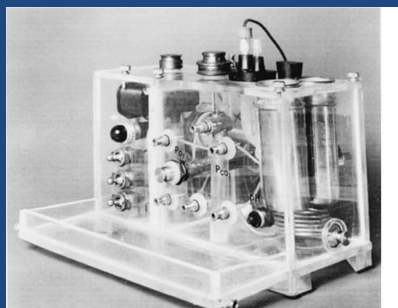
ABG Analyzers

First three-function blood gas apparatus (pH, Pco_2, and Po_2 electrodes) built by Severinghaus and Bradley (1959)



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ABG Analyzer Calibration

Example

Barometric pressure 760
Water vapor pressure 47
760 – 47 = 713
713 x 0.05 = 35.65

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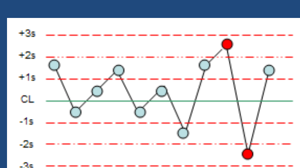
Levey Jennings Chart



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ABG Parameters

The following parameters can be measured on blood:

Parameter group	Parameters
pH/blood gas:	pH (acidity)
	pCO_2 (carbon dioxide tension)
	pO_2 (oxygen tension)
Oximetry:	ctHb (total hemoglobin concentration)
	sO_2 (oxygen saturation)
	FO_2Hb (fraction of oxyhemoglobin in total hemoglobin)
	FCOHb (fraction of carboxyhemoglobin in total hemoglobin)
	FHHb (fraction of deoxyhemoglobin in total hemoglobin)
	FMetHb (fraction of methemoglobin in total hemoglobin)
	FHbF (fraction of fetal hemoglobin)
Electrolytes:	cK^+ (potassium ion concentration)
	cNa^+ (sodium ion concentration)
	cCa^{2+} (calcium ion concentration)
	cCl^- (chloride ion concentration)
Metabolites:	cGlu (D-glucose concentration)
	cLac (L(+)-lactate concentration)
	ctBil (concentration of total bilirubin, measurement in plasma is possible, see *Limitations of use* later in this chapter)
	cCrea (concentration of creatinine, measurement on plasma and serum possible, see *Limitations of use* later in this chapter)

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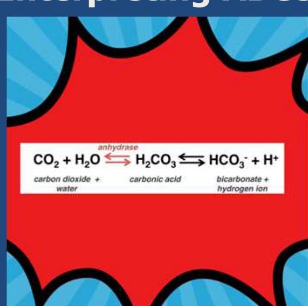
Interpreting ABGs



Total CO_2 is normally around 25 mmol/L & is calculated by taking the bicarbonate and adding 0.03 times the CO_2

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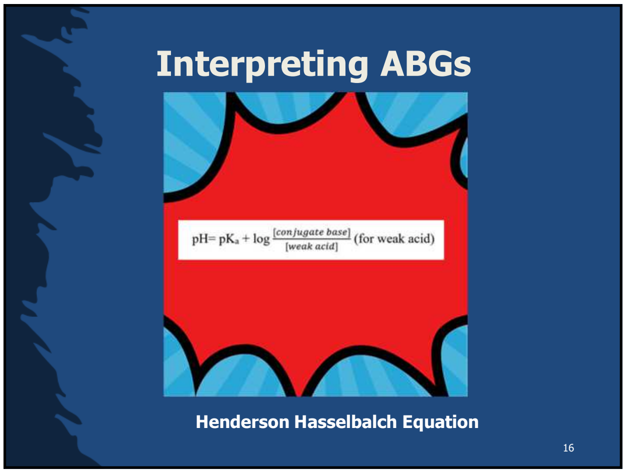
Interpreting ABGs
$pH = pK_a + \log \frac{[conjugate\ base]}{[weak\ acid]}$ (for weak acid)
Henderson Hasselbalch Equation
16

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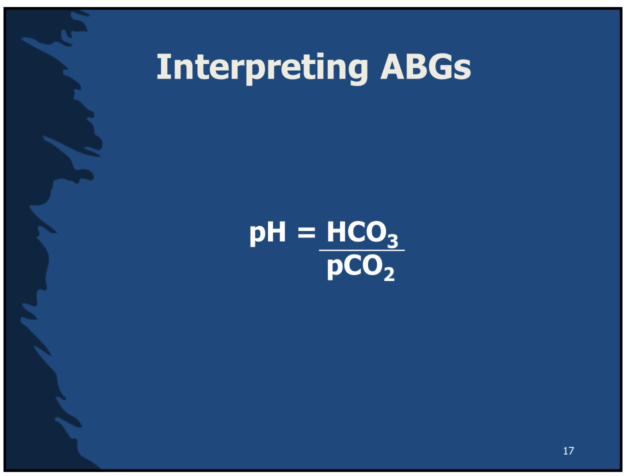
Interpreting ABGs
$pH = \frac{HCO_3}{pCO_2}$
17

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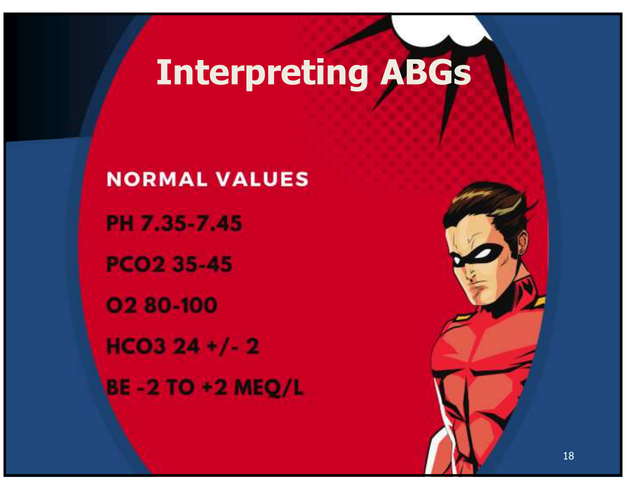
Interpreting ABGs
NORMAL VALUES
PH 7.35-7.45
PCO2 35-45
O2 80-100
HCO3 24 +/- 2
BE -2 TO +2 MEQ/L
18

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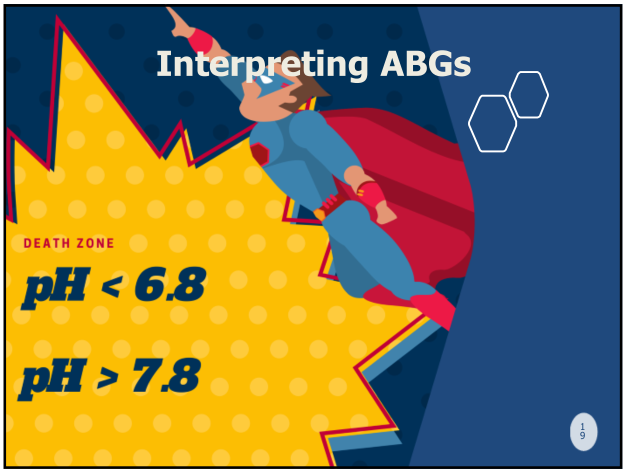

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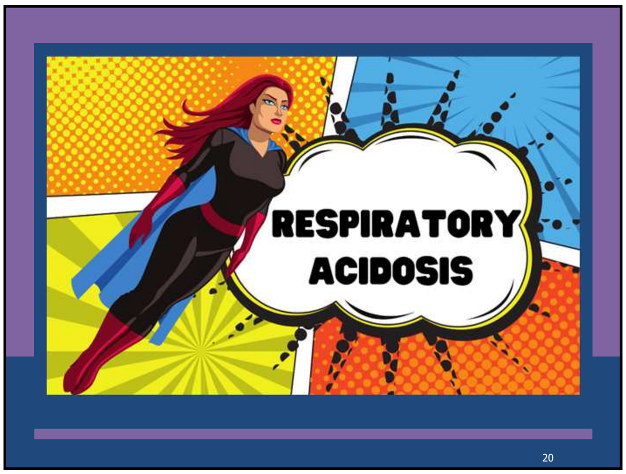

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Respiratory Acidosis

- pH < 7.35
- pCO_2 > 45
- Acute or Chronic

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Acute Respiratory Acidosis

- Headache
- Confusion
- Drowsiness
- Decreased heart contraction force
- Decreased vascular response to catecholamines
- Diminished response to some medications

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Acute Respiratory Acidosis

- Ventilation chain defects
- Increased CO_2 production

$$pH = \frac{24\ HCO_3}{55\ pCO_2}$$

23

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Chronic Respiratory Acidosis

- Increased CO_2
- Increased HCO_3
- Normal pH

$$pH\ 7.37 = \frac{33\ HCO_3}{55\ pCO_2}$$

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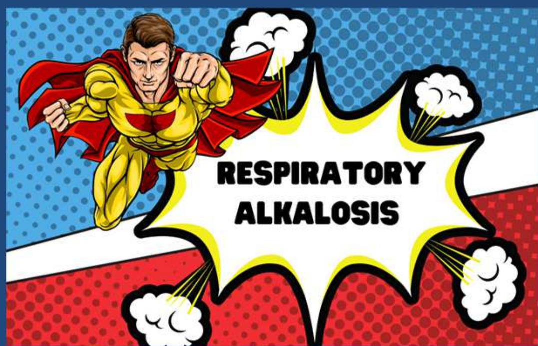

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Respiratory Alkalosis

- $pCO_2 < 35$
- pH > 7.45

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Respiratory Alkalosis

- Anxiety
- Fear
- Pain
- Hypoxemia/Hypoxia
- Increased metabolic demands

$$pH = \frac{24\ HCO_3}{25\ pCO_2}$$

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Respiratory Alkalosis

- Numbness
- Tingling
- Confusion
- Blurred vision
- Muscle spasms
- Diaphoresis
- Dysrhythmias
- Palpitations
- Dry mouth

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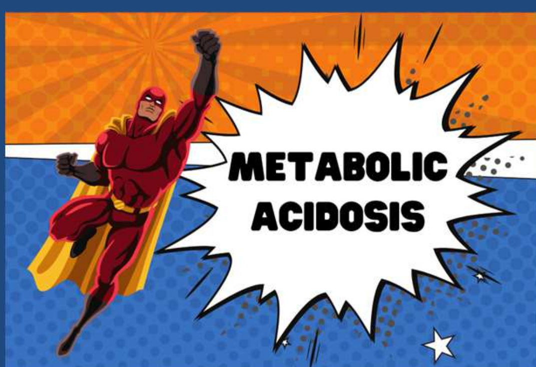

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Metabolic Acidosis

- $HCO_3 < 22$
- $pH < 7.35$

$$pH = \frac{16\ HCO_3}{40\ pCO_2}$$

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Metabolic Acidosis

- Diarrhea
- Renal failure
- Diabetic ketoacidosis (DKA)
- Anaerobic Metabolism
- Starvation
- Salicylates

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Metabolic Acidosis

- Headache
- Confusion
- Coma
- Dysrhythmias
- Kussmaul breathing (DKA)
- Nausea
- Vomiting

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Metabolic Alkalosis

- $HCO_3 > 26$
- $pH > 7.45$

$$pH = \frac{38\ HCO_3}{40\ pCO_2}$$

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Metabolic Alkalosis

- Antacids
- Bicarbonate
- Gastric suctioning
- Vomiting
- Diuretics

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Metabolic Alkalosis

- Respiratory depression
- Dizziness
- Seizures
- Coma
- Muscle twitching
- Cramps
- Nausea
- Vomiting

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Classification of Oxygenation

- 80-100 Normal
- 60-79 Mild
- 40-59 Moderate
- < 40 Severe

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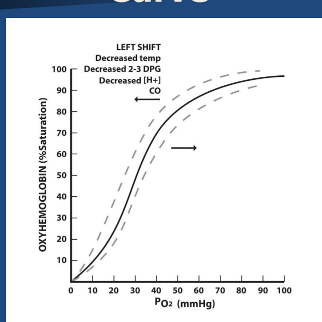
Oxyhemoglobin Dissociation Curve



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Oxyhemoglobin Dissociation Curve

Hot Acid is Right

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Total Oxygen Content

$CaO_2 = (1.34 \times Hb \times SaO_2) + (PaO_2 \times 0.003)$

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Total Oxygen Content

$CaO_2 = (1.34 \times Hb \times SaO_2) + (PaO_2 \times 0.003)$

CaO_2 = 17-20 vol%

42

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Total Oxygen Content

$CaO_2 = (1.34 \times Hb \times SaO_2) + (PaO_2 \times 0.003)$

CaO_2 = 17-20 vol%

CvO_2 = 13-15 vol%

43

43

Total Oxygen Content

$CaO_2 = (1.34 \times Hb \times SaO_2) + (PaO_2 \times 0.003)$

CaO_2 = 17-20 vol%

CvO_2 = 13-15 vol%

$CaO_2 - CvO_2$ = 4-5 vol%

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Interpreting ABGs

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Base Excess

- Normal +/- 2 mEq/L
- pH change of 0.1 = BE 6 mEq/L

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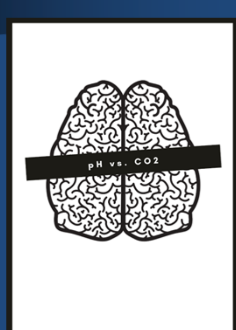
ABG Interpretation



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ABG Interpretation Examples

pH / CO_2 / PO_2 / HCO_3
7.30 / 50 / 65 / 24
7.30 / 50 / 65 / 28
7.36 / 54 / 65 / 30
7.49 / 30 / 65 / 24
7.42 / 30 / 65 / 18
7.30 / 28 / 80 / 19

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Example # 1

- **58 y/o male 5' 9" 295 lbs, has stroke like symptoms**
  Hx: CVA, DM, Obesity

AC-VC 16 / 450 / 5 / FiO_2 50%

7.37 / 47.1 / 72.4 / 26.4 Be 1.3

50

50

Example # 2

- **22 y/o male 6' 1" 146 lbs with AMS & acute encephalopathy**
  Hx: Asthma

AC-VC 16 / 400 / 5 / FiO_2 50%

7.20 / 61 / 254 / 22.7 Be -5.7

51

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Example # 3

- 64 y/o Male 5' 7" 160 lbs, who came in with sepsis
Resp failure ⟶ Failed BiPAP ⟶ Intubated

AC-VC 14 / 450 / 5 / FiO_2 40%

7.42 / 44.5 / 79.4 / 28.4 Be 4.0

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Example # 4

- 46 y/o Female 5' 0" 130 lbs, SOB x 8 days ⟶ COVID+

AC-PC f26 / (Inspiratory Pressure) Pi 23 / (Inspiratory Time) Ti 1.0 / 5 / FiO_2 100%

7.29 / 62.8 / 53.1 / 29 Be 1.6

53

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Example # 5

- 44 y/o Male 5' 6" 223 lbs. Came in with urinary retention & lower extremity edema

Hx: CHF (EF 20-25%), HTN, OSA, Obesity, pre-DM

BiPAP 24 / 5 / FiO_2 40%

7.54 / 43.1 / 96.8 / 37.1 Be 12.8

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ANION GAP

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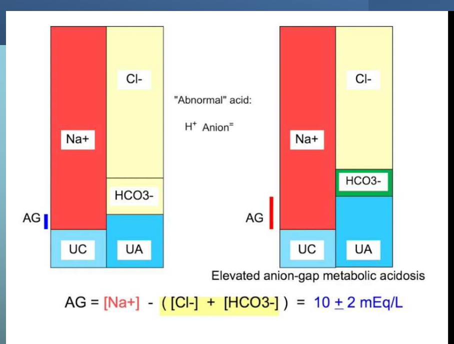
Anion Gap



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Normal Anion Gap (NAGMA)

- A Addison's Disease
- B Bicarbonate Loss
  - Diarrhea
  - Renal Tubular Acidosis
- C Chloride Excess – too much 0.9% NaCl
- D Drugs

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High Anion Gap (HAGMA)

- Dehydration
- Kidney Disease
- Diabetes
- Lactate
- Other causes

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High Anion Gap (HAGMA)

- LTKR
  - Lactate
  - Toxins
  - Ketones
  - Renal Failure

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High Anion Gap (HAGMA)

- KARMEL
  - Ketones
  - Aspirin
  - Renal Failure
  - Methanol
  - Ethylene Glycol
  - Lactate

60

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High Anion Gap (HAGMA)

- CAT MUDPILES - The Exhaustive List
  - Cyanide (and CO)
  - Alcoholic Ketoacidosis
  - Toluene
  - Methanol, metformin
  - Uremia
  - Diabetic Ketoacidosis
  - Paracetamol
  - Iron, isoniazid
  - Lactate
  - Ethanol, Ethylene Glycol
  - Salicylate

61

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High Anion Gap (HAGMA)

- GOLDMARK – Replaces MUDPILES
  - Glycols
  - Oxoproline
  - Lactate
  - D-Lactate
  - Methanol
  - Aspirin
  - Renal Failure
  - Ketoacidosis

62

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Low Anion Gap

- Low Albumin

63

63

Example # 1

- 58 y/o male 5' 9" 295 lbs, has stroke like symptoms
Hx: CVA, DM, Obesity

AC-VC 16 / 450 / 5 / FiO_2 50%

7.37 / 47.1 / 72.4 / 26.4 Be 1.3

Na+ 141
K+ 3.4
Cl- 107
HCO_3 26.4

64

64

Example # 1

- 58 y/o male 5' 9" 295 lbs, has stroke like symptoms
Hx: CVA, DM, Obesity

AC-VC 16 / 450 / 5 / FiO_2 50%

7.37 / 47.1 / 72.4 / 26.4 Be 1.3

Na+ 141
Cl- 107
HCO_3 26.4

141 – (107 + 26.4) = Gap 7.6

65

65

Example # 2

- 22 y/o male 6' 1" 146 lbs with AMS & acute encephalopathy
Hx: Asthma

AC-VC 16 / 400 / 5 / FiO_2 50%

7.20 / 61 / 254 / 22.7 Be -5.7

Na+ 140
Cl- 109
HCO_3 22.7

140 – (109 + 22.7) = Gap 8.3

66

66

Example # 3

- 46 y/o male 5' 1" 295 lbs with C.P. & SOB

HFNC 10 LPM

7.32 / 45.3 / 69.3 / 22.5 Be -3.1

Na+ 130
Cl- 94
HCO_3 22.5

130 – (94 + 22.5) = Gap 13.5

67

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Delta-Delta Gap

$$\frac{\text{Change in Anion Gap}}{\text{Change in Bicarbonate}}$$

68

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Delta-Delta Gap

$$\frac{\text{Calculated AG} - \text{Expected AG}}{24 - HCO_3}$$

69

69

Delta-Delta Gap

$$\frac{\text{Calculated AG} - 12}{24 - HCO_3}$$

70

70

Example # 3

- 46 y/o male 5′ 1″ 295 lbs with C.P. & SOB

HFNC 10 LPM

7.32 / 45.3 / 69.3 / 22.5 Be -3.1

Na+ 130
Cl- 94
HCO_3 22.5

130 – (94 + 22.5) = Gap 13.5

71

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Delta-Delta Gap

$$\frac{\text{Calculated AG} - \text{Expected AG}}{24 - HCO_3}$$

$$\frac{13.5 - 12}{24 - 22.5}$$

$$\frac{1.5}{1.5}$$

Quotient of 1.0

72

72

Delta-Delta Gap

0.4 = normal anion gap metabolic acidosis

0.4 – 0.8 = mixed high and normal anion gap acidosis exists

0.8 – 1.0 = purely due to a high anion gap metabolic acidosis

1.0 – 2.0 = still purely a high anion gap metabolic acidosis

Over 2.0 = high anion gap acidosis with pre-existing metabolic alkalosis (high HCO_3)

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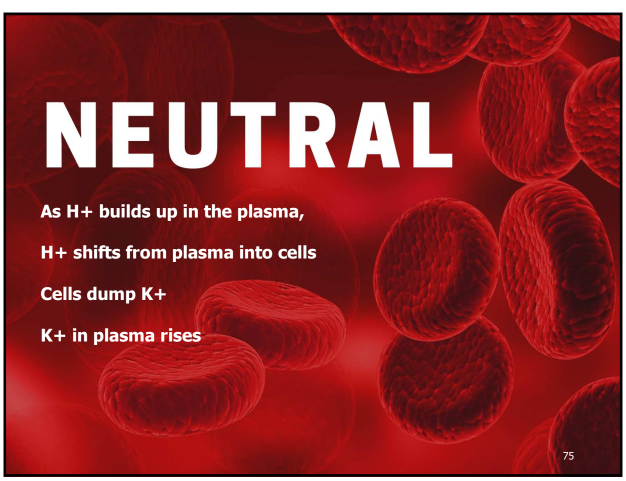

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Recap
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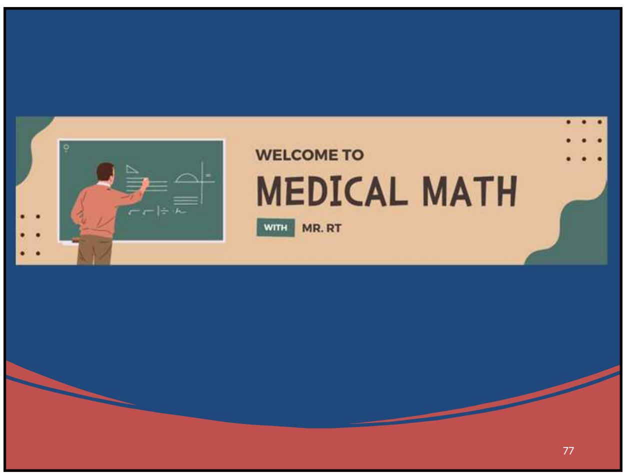
WELCOME TO
MEDICAL MATH
WITH
MR. RT
77

77


HELLO
my name is
SWAG
78

78

Medical Math

(current) Ve x CO_2 = Ve x CO_2 (future)

79

79

Medical Math

RR x CO_2 = RR x CO_2

or

VT x CO_2 = VT x CO_2

80

80

Predicted Body Weight kg

- Males 50 +2.3 per inch above 60”
- Females 45.5 +2.3 per inch above 60”

81

81

Predicted pH Changes

pH 0.1 = 12 pCO_2 = 6 BE

82

82

Example # 2

- 22 y/o male 6′ 1″ 146 lbs with AMS & acute encephalopathy

Hx: Asthma

AC-VC 16 / 400 / 5 / FiO_2 50%

7.20 / 61 / 254 / 22.7

83

83

Example # 2

- 22 y/o male 6′ 1″ 146 lbs with AMS & acute encephalopathy

Hx: Asthma

AC-VC 16 / 400 / 5 / FiO_2 50%

7.20 / 61 / 254 / 22.7

PBW: Male 50 +2.3 per inch above 60″
6′ 1″ = 73″
73 – 60 = 13
50 + (2.3 x 13) = 50 + 29.9 = 79.9

PBW = 80

84

84

Example # 2

- 22 y/o male 6′ 1″ 146 lbs with AMS & acute encephalopathy

Hx: Asthma

AC-VC 16 / 400 / 5 / FiO_2 50%

7.20 / 61 / 254 / 22.7

PBW = 80

VT Range = 480-640

85

85

Example # 2

A/C 16 / 400 / 5 / FiO_2 50%   7.20 / 61 / 254 / 22.7

pH needs to change by 0.15 to reach 7.35 (pH 0.1 = 12 CO_2)
0.15 / 0.1 = 1.5
12 x 1.5 = 18
61 – 18 = 43 (desired CO_2)
PBW = 80   VT Range = 480-640   Ve 6,400

(current) Ve x CO_2 = Ve x CO_2 (future)

6,400 x 61 = 480 x rr x 43
390,400 = 20,640 x rr
18.9 = rr

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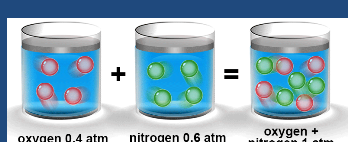
Dalton's Law



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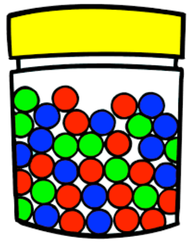
Dalton's Law



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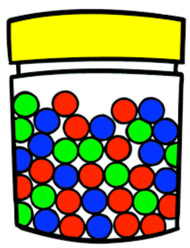
Dalton's Law



$PAO_2 = (FiO_2 \times (PB-47)) - (CO_2 \times 1.25)$

89

89

Short Cuts

- $(FiO_2 \times 7) - (CO_2 + 10)$
- PAO_2 on 50% = 300

90

90

$A\text{-}aDO_2$

- $A\text{-}aDO_2 = (PAO_2 – PaO_2)$
- Normal around 5 on RA
- Should be < 100
- Should be less than FiO_2

91

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Chronic CO_2 Retainer

$CO_2 = 65$

What would his normal PO_2 be?

92

92

Chronic CO_2 Retainer

$CO_2 = 65$

(0.21 x (760-47)) – (65 x 1.25)
(0.21 x 713) – 81.25
150 – 81
69-5 (assuming A-a of 5)
64

93

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FiO_2 Math

New FiO_2 = $\frac{\text{Desired } PaO2 \text{ x Known } FiO_2}{\text{Known } PaO_2}$

94

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Using Pa/A O_2 in Calculations

- Predicting PaO_2 for changed FiO_2

ABGs: FiO_2 = 0.6, PaO_2 = 50, $PaCO_2$ = 30
Increasing FiO_2 to 0.7 will produce what PaO_2?

Use alveolar air equation to find Pa/A O_2

PAO_2 = (0.6 x 713) – (30 x 1.25) = 390

PaO_2 / PAO_2 = 50 / 390 = 0.13

95

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Using Pa/A O_2 in Calculations

- Predicting PaO_2 for changed FiO_2

Increasing FiO_2 to 0.7 will produce what PaO_2?

FiO_2 = 0.7
PAO_2 = (0.7 x 713) – (30 x 1.25) = 462

PaO_2 / PAO_2 = 50 / 390 = 0.13 (original)
0.13 x 462 = 60

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Pa/FiO_2 Ratio

- Common index for clinical settings & research
- Values
  - Normal 95 / 0.21 = 452
  - Acute lung injury: PaO_2 / FiO_2 = < 300
  - ARDS: PaO_2 / FiO_2 = < 200
- Disadvantages
  - Index changes with FiO_2
  - Does not consider lung mechanics

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Pa/FiO_2 Ratio

p/f ratio = Pa / FiO_2

a / (FiO_2 x (PB-47)) – (CO_2 x 1.25)

98

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Pa/FiO_2 Ratio

p/f ratio = Pa / FiO_2

A/C 16 / 400 / 5 / FiO_2 50%   7.20 / 61 / 254 / 22.7

254 / 0.50 = 508

99

99

Pa/FiO_2 Ratio

p/f ratio = Pa / FiO_2

A/C 16 / 400 / 5 / FiO_2 50% 7.20 / 61 / 254 / 22.7

254 / 0.50 = 508

100 / 508 = 19.6

100

100

Oxygen Index (OI)

- For patients on CMV
- Pediatric clinical settings & research
- Calculation

  $$OI = \frac{FiO_2 \times MAP \times 100}{PaO_2}$$

- Values
  - Very good < 5
  - Medium 10 - 20
  - Poor > 25

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Oxygen Index (OI)

- Advantages
  - Considers lung mechanics (mean airway pressure)
  - Prognostic value: Greater OI → risk for mortality

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Winter's Function

- Predicted $PaCO_2 = 1.5 \times [HCO_3^-] + 8 \ (+/- 2)$

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PaCO-PeCO-PaCO

- $PaCO_2 - PETCO_2 / PaCO_2$

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PaCO-PeCO-PaCO

- $PaCO_2 - PETCO_2 / PaCO_2$
- 7.32 / 45.3 / 69.3 / 22.5 $PETCO_2$ 35

45 – 35 = 10

10/45 = 22%

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BiPAP

- **7.28 / 55.3 / 82 / 22.5 9/5 40%**
- **7.28 / 55.3 / 112 / 22.5 14/10 40%**

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Summary & Review

- **ABG analyzer quality & control**
- **Avoidance of pre-analytical errors**
- **Normal ABG values**
- **ABG Interpretation**
- **Anion Gap**
- **Delta-delta**
- **Medical math**

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Sources

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