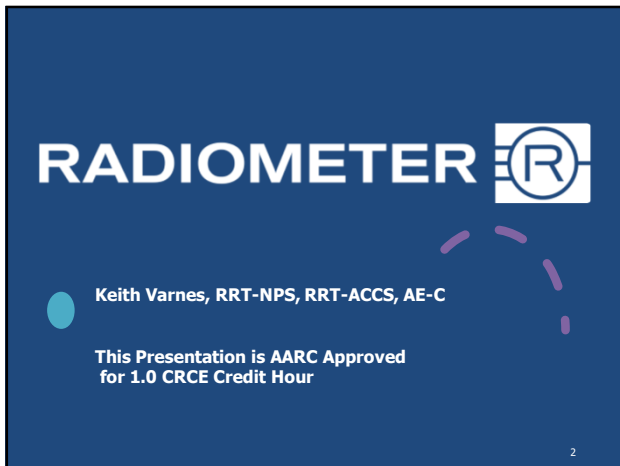
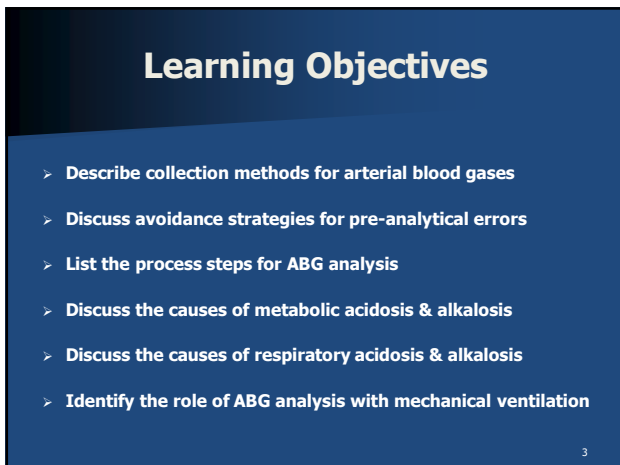




1



2



3

Roche v-TAC

Software application to calculate arterial blood gas values from venous blood

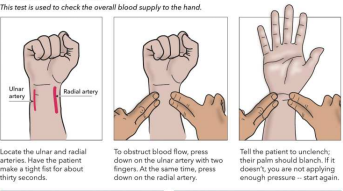
ROCHE

4

4

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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5

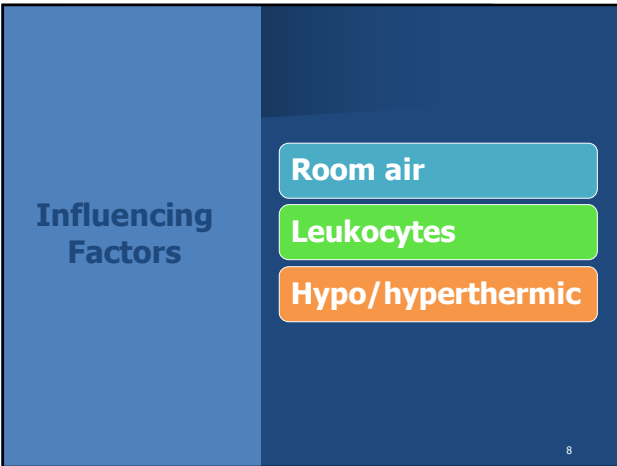
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7



8



9



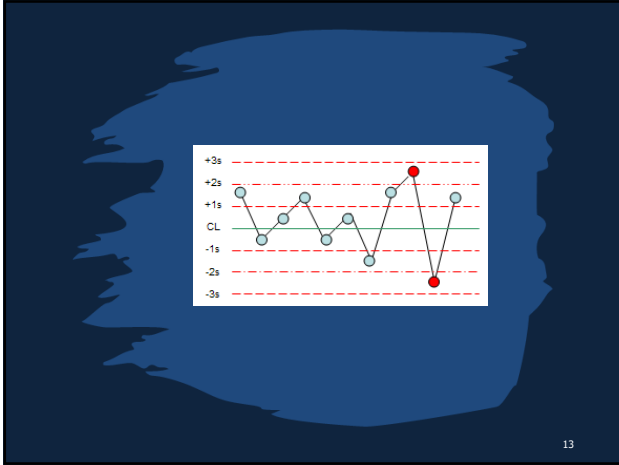
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11



12



13

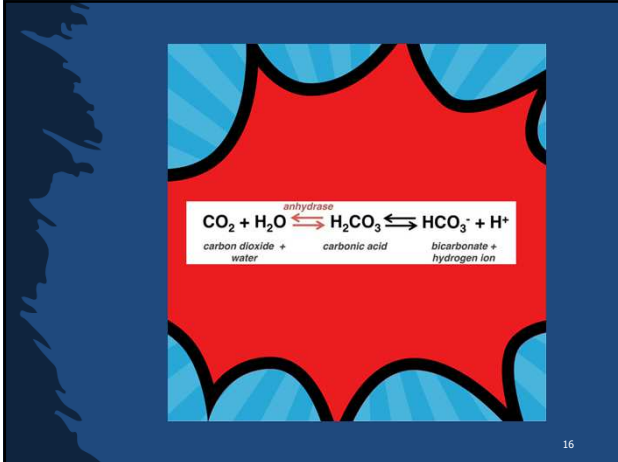
The following parameters can be measured on blood:

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)
	FOHb (fraction of oxyhemoglobin in total hemoglobin)
	FCOHb (fraction of carboxyhemoglobin in total hemoglobin)
	FMHb (fraction of desoxyhemoglobin in total hemoglobin)
	FMeHb (fraction of methemoglobin in total hemoglobin)
	FHbF (fraction of fetal hemoglobin)
Electrolytes:	eK ⁺ (potassium ion concentration)
	eNa ⁺ (sodium ion concentration)
	eCa ²⁺ (calcium ion concentration)
	eCl ⁻ (chloride ion concentration)
	eGlu (D-glucose concentration)
Metabolites:	eLac (L(+)-lactate concentration)
	eBil (concentration of total bilirubin, measurement in plasma is possible, see <i>Limitations of use</i> later in this chapter)
	eCrea (concentration of creatinine, measurement on plasma and serum possible, see <i>Limitations of use</i> later in this chapter)

14



15



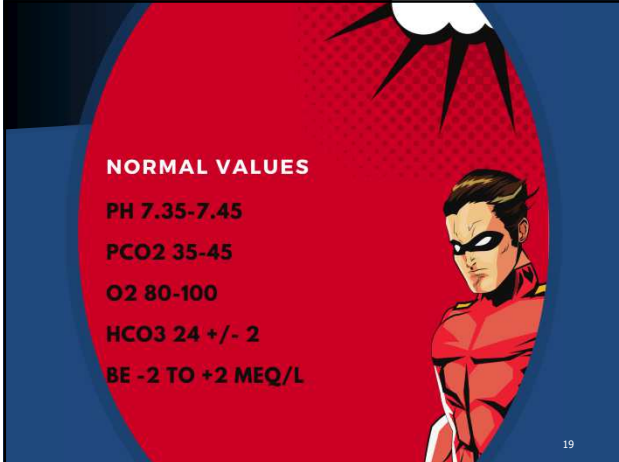
16

$$\text{pH} = \text{pK}_a + \log \frac{[\text{conjugate base}]}{[\text{weak acid}]} \text{ (for weak acid)}$$

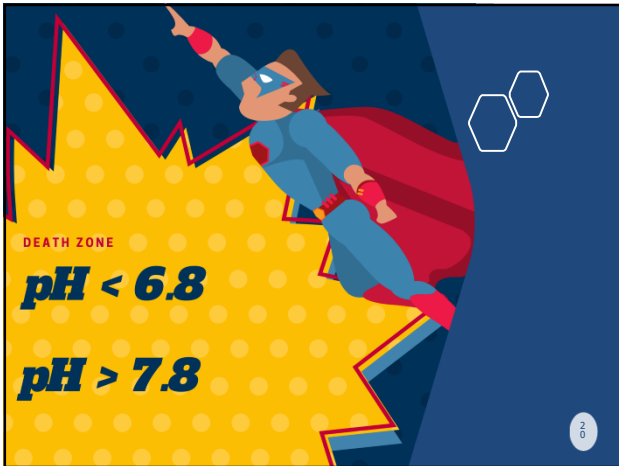
17

$$\text{pH} = \frac{\text{HCO}_3}{\text{pCO}_2}$$

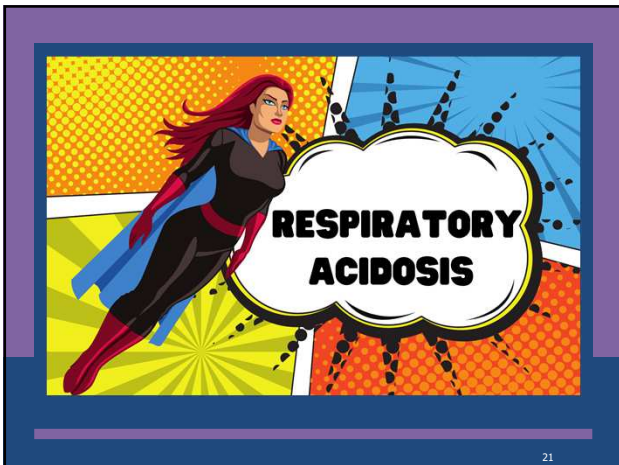
18



19



20



21

Respiratory Acidosis

- > pH < 7.35
- > pCO₂ > 45
- > Acute or Chronic

22

22

Acute Respiratory Acidosis

- > Headache
- > Confusion
- > Drowsiness
- > Heart Contraction
- > Catecholamines
- > Medications

23

23

Acute Respiratory Acidosis

- > Ventilation chain defect
- > Increased CO₂ production

$$\text{pH} = \frac{24 \text{ HCO}_3}{55 \text{ pCO}_2}$$

24

24

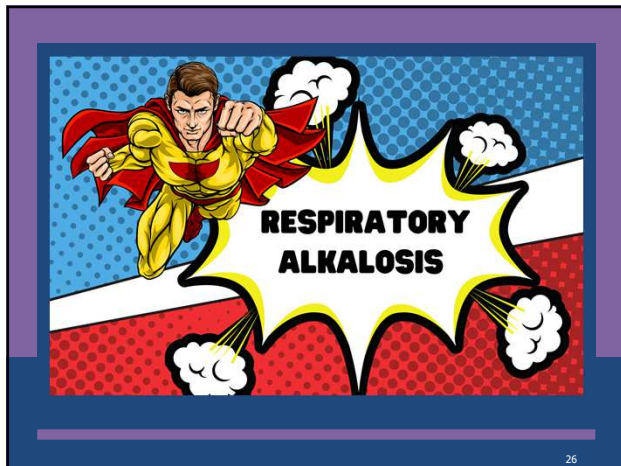
Chronic Respiratory Acidosis

- > Increased CO₂
- > Increased HCO₃
- > Normal pH

$$\text{pH } 7.37 = \frac{33 \text{ HCO}_3}{55 \text{ pCO}_2}$$

25

25



26

26

Respiratory Alkalosis

- > pCO₂ < 35
- > pH > 7.45

27

27

Respiratory Alkalosis

- > Pain
- > Fear
- > Hypoxia
- > Increased metabolic demands

$$\text{pH} = \frac{24 \text{ HCO}_3}{25 \text{ pCO}_2}$$

28


28

Respiratory Alkalosis

- > Numbness
- > Tingling
- > Confusion
- > Blurred Vision
- > Muscle Spasms
- > Dysrhythmias

29

29



**METABOLIC
ACIDOSIS**

30

30

Metabolic Acidosis

- > $\text{HCO}_3 < 22$
- > $\text{pH} < 7.35$

$$\text{pH} = \frac{16 \text{ HCO}_3}{40 \text{ pCO}_2}$$

31

31

Metabolic Acidosis

- > Diarrhea
- > Renal failure
- > DKA
- > Anaerobic Metabolism
- > Anaerobic Metabolism
- > Starvation
- > Salicylates

32

32

Metabolic Acidosis

- > Headache
- > Confusion
- > Coma
- > Dysrhythmias
- > Kussmaul Breathing (DKA)
- > Nausea
- > Vomiting

33

33



34

Metabolic Alkalosis

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

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

35

Metabolic Alkalosis

- > Antacids
- > Bicarbonate
- > Gastric Suctioning
- > Vomiting
- > Diuretics

36

Metabolic Alkalosis

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

37

37



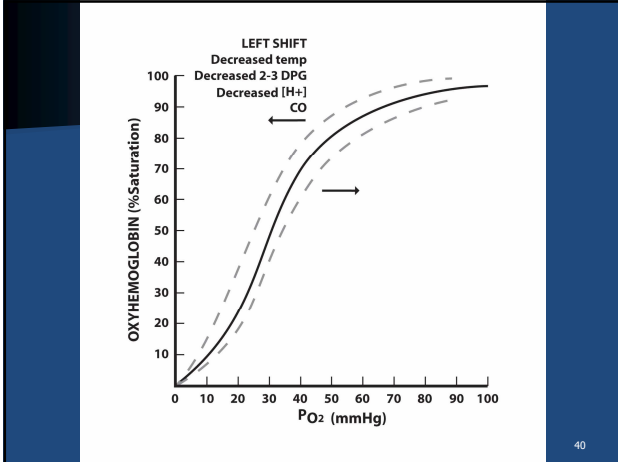
38

Classification of Oxygenation

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

39

39



40

Hot Acid is Right

41

Total Oxygen Content

$CaO_2 = (1.34 \times Hb \times SaO_2) + (PaO_2 \times .003)$

42

Total Oxygen Content

$$CaO_2 = (1.34 \times Hb \times SaO_2) + (PaO_2 \times .003)$$
$$CaO_2 = 17-20 \text{ vol\%}$$

43

43

Total Oxygen Content

$$CaO_2 = (1.34 \times Hb \times SaO_2) + (PaO_2 \times .003)$$
$$CaO_2 = 17-20 \text{ vol\%}$$
$$CvO_2 = 13-15 \text{ vol\%}$$

44

44

Total Oxygen Content

$$CaO_2 = (1.34 \times Hb \times SaO_2) + (PaO_2 \times .003)$$
$$CaO_2 = 17-20 \text{ vol\%}$$
$$CvO_2 = 13-15 \text{ vol\%}$$
$$CaO_2 - CvO_2 = 4-5 \text{ vol\%}$$

45

45



46



47

Base Excess

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

A small number '48' is in the bottom right corner.

48



49

Examples

- 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

50

Example # 1

> 58 y/o male 5' 9" 295 lbs. Stroke like symptoms
Hx: CVA, DM, Obesity

A/C 16/450/5 FiO2 50%

7.37/47.1/72.4/26.4 Be 1.3

51

Example # 2

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

A/C 16/400/5 FiO2 50%

7.20/61/254/22.7 Be -5.7

52

52

Example # 3

> 64 y/o Male 5' 7" 160 lbs. Sepsis
Resp failure → Failed BiPAP → Intubated

A/C 14/450/5 FiO2 40%

7.42/44.5/79.4/28.4 Be 4.0

53

53

Example # 4

> 46 y/o Female 5' 0" 130 lbs. SOB x 8 days → COVID+

AC-PC f26/Pi 23/ Ti 1.0 / 5 FiO2 100%

7.29/62.8/53.1/29 Be 1.6

54

54

Example # 5

> 44 y/o Male 5' 6" 223 lbs. Urinary retention & Lower Extremity Edema

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

BiPAP 24/5 40%

7.54/43.1/96.8/37.1 Be 12.8

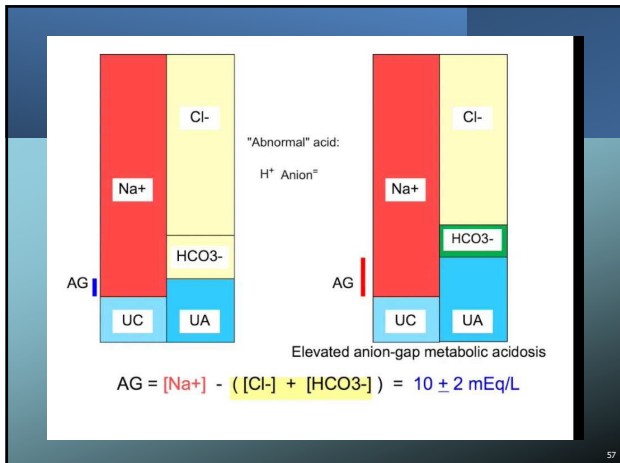
55

55



56

56



57

57

Raised Anion Gap

- > Dehydration
- > Kidney Disease
- > Lactate

58

58

Normal Anion Gap

- > Diarrhea
- > Renal Tubular Acidosis

59

59

Low Anion Gap

- > Low Albumin

60

60

Example # 1

> 58 y/o male 5' 9" 295 lbs. Stroke like symptoms
Hx: CVA, DM, Obesity

A/C 16/450/5 FiO2 50%

7.37/47.1/72.4/26.4 Be 1.3

Na+ 141
K+ 3.4
Cl- 107
HCO3 26

61

61

Example # 1

> 58 y/o male 5' 9" 295 lbs. Stroke like symptoms
Hx: CVA, DM, Obesity

A/C 16/450/5 FiO2 50%

7.37/47.1/72.4/26.4 Be 1.3

Na+ 141
Cl- 107
HCO3 26.4

Gap = 7.6

62

62

Example # 2

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

A/C 16/400/5 FiO2 50%

7.20/61/254/22.7 Be -5.7

Na+ 140
Cl- 109
HCO3 22.7

63

63

Example # 2

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

A/C 16/400/5 FiO2 50%

7.20/61/254/22.7 Be -5.7

Na+ 140
Cl- 109
HCO3 22.7

Gap 8.3

64

64

Example # 3

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

HFNC 10 LPM

7.32/45.3/69.3/22.5 Be -3.1

Na+ 130
Cl- 94
HCO3 22.5

65

65

Example # 3

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

HFNC 10 LPM

7.32/45.3/69.3/22.5 Be -3.1

Na+ 130
Cl- 94
HCO3 22.5

Gap 13.5

66

66

Delta-Delta Gap

Change in Anion Gap
Change in Bicarbonate

67

67

Delta-Delta Gap

Calculated AG-Expected AG
24-HCO₃

68

68

Delta-Delta Gap

Calculated AG-12
24-HCO₃

69

69

Example # 3

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

HFNC 10 LPM

7.32/45.3/69.3/22.5 Be -3.1

Na+ 130
Cl- 94
HCO3 22.5

Gap 13.5

70

70

Delta-Delta Gap

$\frac{14-12}{24-22.5}$

71

71

Delta-Delta Gap

$\frac{2}{1.5}$

72

72

Delta-Delta Gap

$2 / 1.5 = 1.3$

73

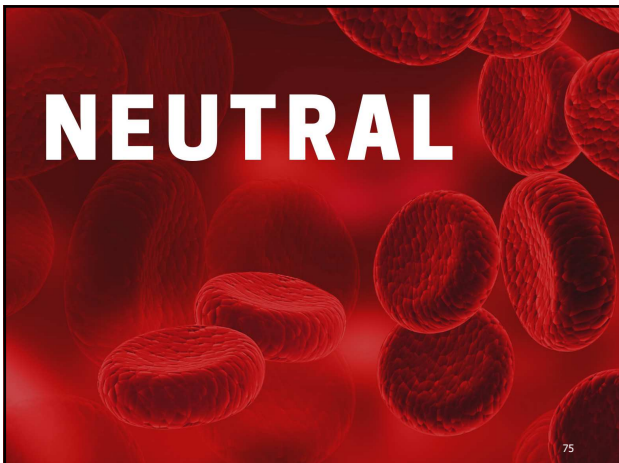
73

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 HCO₃)

74

74



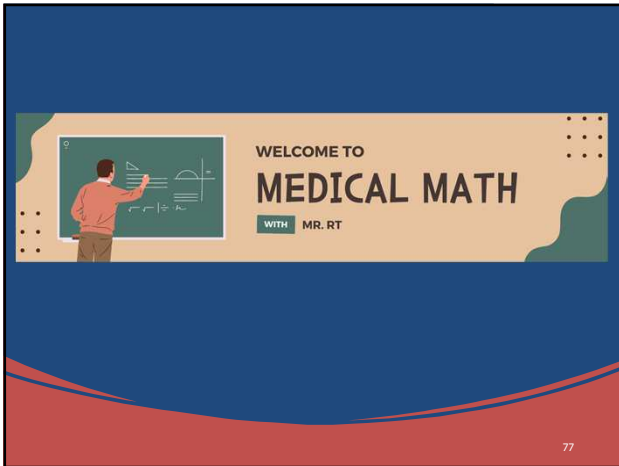
NEUTRAL

75

75



76



77



78

(current) $V_e \times CO_2 = V_e \times CO_2$ (future)

79

$RR \times CO_2 = RR \times CO_2$
or
 $VT \times CO_2 = VT \times CO_2$

80

Predicted Body Weight kg

- > Males $50 + 2.3 (\text{height} - 60 \text{ in})$
- > Females $45.5 + 2.3 (\text{height} - 60 \text{ in})$

81

Predicted pH Changes

pH 0.1 = 12 pCO2 = 6 BE

82

82

Example # 2

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

A/C 16/400/5 FiO2 50%

7.20/61/254/22.7

83

83

Example # 2

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

A/C 16/400/5 FiO2 50%

7.20/61/254/22.7

PBW = 80

84

84

Example # 2

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

A/C 16/400/5 FiO2 50%

7.20/61/254/22.7

PBW = 80

VT Range = 480-640

85

85

Example # 2

A/C 16/400/5 FiO2 50% 7.20/61/254/22.7

PBW = 80 VT Range = 480-640

61-18 = 43

6400 x 61 = 480 x rr x 43

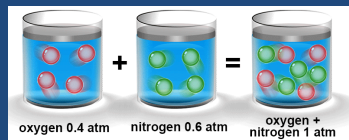
390,400 = 20,640 x rr

18.9 = rr

86

86

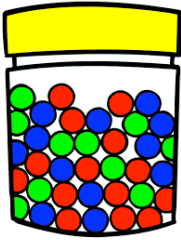
Dalton's Law



87

87

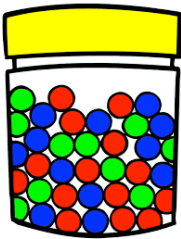
Dalton's Law



88

88

Dalton's Law

$$PAO_2 = FIO_2(PB-47) - (CO_2 * 1.25)$$


89

89

Short Cuts

- $(FIO_2 \times 7) - (CO_2 + 10)$
- PAO₂ on 50% = 300

90

90

A-aDO₂

- $A-aDO_2 = (PAO_2 - PaO_2)$
- Should be < 100
- Should be less than FiO_2

91

91

FiO₂ Math

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

92

92

Using Pa/A O₂ 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 O₂

$$PAO_2 = 0.6 (713) - (30 \times 1.25) = 390$$

$$PaO_2 / PAO_2 = 50 / 390 = 0.13$$

93

93

Using Pa/A O₂ in calculations

> Predicting PaO₂ for changed FiO₂

Increasing FiO₂ to 0.7 will produce what PaO₂?

FiO₂ = 0.7

PAO₂ = 0.7 (713) - (30 * 1.25) = 462

PaO₂/PAO₂ = 50/390 = 0.13 (original)

0.13 * 462 = 60

94

94

Pa/FiO₂ Ratio

> Common index for clinical settings & research

> Values

❖ Normal 95 / 0.21 = 452

❖ Acute lung injury: PaO₂ / FiO₂ = < 300

❖ ARDS: PaO₂ / FiO₂ = < 200

> Disadvantages

❖ Index changes with FiO₂

❖ Does not consider lung mechanics

95

95

Pa/FiO₂ Ratio

p/f ratio = Pa / FiO₂

a / FiO₂(PB-47) - (CO₂ * 1.25)

96

96

Pa/FiO₂ Ratio

p/f ratio = Pa / FiO₂

A/C 16/400/5 FiO₂ 50% 7.20/61/254/22.7

254/.50 = 508

$$\frac{254}{.5} = 508$$

97

97

Pa/FiO₂ Ratio

p/f ratio = Pa / FiO₂

A/C 16/400/5 FiO₂ 50% 7.20/61/254/22.7

254/.50 = 508

$$\frac{254}{.5} = 508$$

$$\frac{100}{508} = 19.6$$

98

98

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

99

99

Oxygen Index (OI)

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

100

100

PaCO-PeCO-PaCO

- > PaCO₂ – PETCO₂ / PaCO₂

101

101

PaCO-PeCO-PaCO

- > PaCO₂ – PETCO₂ / PaCO₂
- > 7.32/45.3/69.3/22.5 PETCO₂ 35

45-35=10

10/45 = 22%

102

102

BiPAP

- **7.28/55.3/82/22.5 9/5 40%**

- **7.28/55.3/112/22.5 14/10 40%**

103

103

Summary & Review

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

104

104

Sources

- Allen, Desmond. *Rapid ABG Interpretation: BiPAP & Ventilator Handbook For MDs, RRTs, & RNs. Avoidance of pre-analytical errors*
- Abelow, Benjamin. *The Painless Guide to Mastering Clinical Acid-Base.*
- Youtman, Maria. *Arterial Blood Gases Interpretation: Master the ABGs in Less Than 24 Hours with More than 40 Questions with Full Answers & Rationales, An Easy ABGs Reference for RN's & School Nursing Students.*

105

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