



Arterial Blood Gas

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Objectives

- # Indications
 - # How to take a blood gas
 - # What the machine measures or what it derives
 - # How to interpret
 - # How to manage
-

Indications

- # Respiratory distress
- # Baby on oxygen
- # Shock
- # Sepsis
- # Suspected metabolic disorder
- # Failure to thrive (weight loss or no wt gain)



Proper samples

- # Arterial stab sample
 - # Arterial indwelling catheter
 - # Arterialized capillary sample
 - # Venous sample
-



Which artery ?

Preferred : Radial , Umbilical

Avoid : Femoral , Brachial, Dorsalis

Allen Test for radial artery puncture



Indwelling catheters

- # Assure free flow
- # Draw sample slowly
- # Remove 4 times the dead space, take sample and inject the same fluid and blood back
- # Run modified Heparin(1U/ml) 0.5 to 1ml /hour (36 ml of distilled water and 4ml Heparin: each ml of Heparin is 40U)



Arterialized capillary sample

- # Warm the heel to cause local vasodilation
 - # Warm water or steam towel
(42-43 C for 5-7 min)
 - # Avoid squeezing
 - # Fill drop from ‘tissue’
 - # Rotate sample to mix heparin well
-



Proper samples: Venous blood

Useful only for SBC and BE estimation

Comparison of ABG at different sites

	Arterial	Capillary	Venous
pH	Same	↔	Same
pO ₂	Higher	→	Lower
pCO ₂	Lower	←	Higher
HCO ₃	Same	↔	Same
Reco-	Good	Fair	Bad

mandation



Arterial blood

Precautions for ABG collection

Use low strength heparin i.e. 1000u/ml

Use minute volume of heparinised saline

Expel air, cap syringe, process immediately

Transport in ice if delay in processing



Process sample immediately

- # Within 30 minutes or earlier
 - # Slush of ice, freezer (max 2 hr)
 - # Report lag time
 - # Shake, homogenise, expel a few drops before processing
-



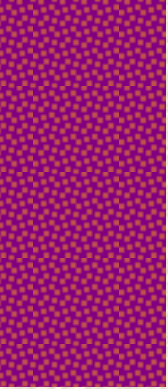
Blood a living medium (in vitro changes every 10 mts)

	37°C	4°C
pH	0.01	0.001
pCO ₂	0.1 mmHg	0.01 mmHg
pO ₂	0.1 vol%	0.01 vol%



Contamination by ambient air

- # Avoid bubble, tighten cap
- # Eliminate air bubble carefully before sending sample
- # An air bubble would show falsely high O_2 and low CO_2



Normal neonatal ABG values

pH	7.35-7.40
pCO ₂	35-45 mmHg
pO ₂	50-70 mmHg
HCO ₃ ⁻	20-24 m Eq/L
BE	± 2

Terminology of ABG

Acidosis	$\text{pH} < 7.3$
Alkalosis	$\text{pH} > 7.5$
Hypercapnia	$\text{pCO}_2 > 45 \text{ mmHg}$
Hypocapnia	$\text{pCO}_2 < 35 \text{ mmHg}$
Hypoxia	$\text{pO}_2 < 50 \text{ mmHg}$
Hyperoxia	$\text{pO}_2 > 70 \text{ mmHg}$



Actual bicarbonate (HCO_3)
20-24 m Eq/L

Acidosis <20 m Eq/L

Alkalosis >24 m Eq/L

What does the machine do?

- # Measures pH , pCO₂ and pO₂
 - # Uses Siggaard Andersen nomogram, O₂ dissociation curve and alveolar gas equation
 - # Calculates rest of the parameters
-



Overall Function of Machine

Measured values

pH

pCO₂

PO₂

Calculated values

ABE, SBE

HCO₃


TCO₂

SpO₂

O₂ content

AaDO₂

a/A ratio



Information to be provided to the machine

Hb

Temperature

FiO₂

Pulse oximetry versus ABG

- # Non invasive
- # Continuous
- # O₂ saturation (SaO₂)
- # Measures oxygenation
- # Bed side monitor
- # Invasive
- # Intermittent
- # Partial pressure of O₂
- # Measures O₂, pH, CO₂, HCO₃
- # Gold standard

Hence both may be required

Calculated values

O₂CT

Hb x 1.34 ml x SaO₂

+

0.003 ml x PaO₂

= ml/100 ml plasma

Alveolar gas equation

A (alveolar) – a (arterial) DO₂ =

$$(\text{Baro} - \text{H}_2\text{O pressure}) \times \text{FiO}_2 - \text{paCO}_2 / R$$

a/A O₂

Alveolar gas equation

A-a DO₂

Normal

Room air : A-a DO₂ < 10 mmHg

100% fiO₂ : A-a DO₂ 200 mmHg

Hence A-a DO₂ is fiO₂ dependent

Ratio a/AO₂

Normal subjects

Room air : 100/ 110 = 0.9

100% fiO₂ : 473/ 673 = 0.7

The ratio is fiO₂ independent

Severe disease < 0.22



Available instrument

Measure: pH, pCO₂

Others derived HCO₃⁻, SBC, BE, SBE

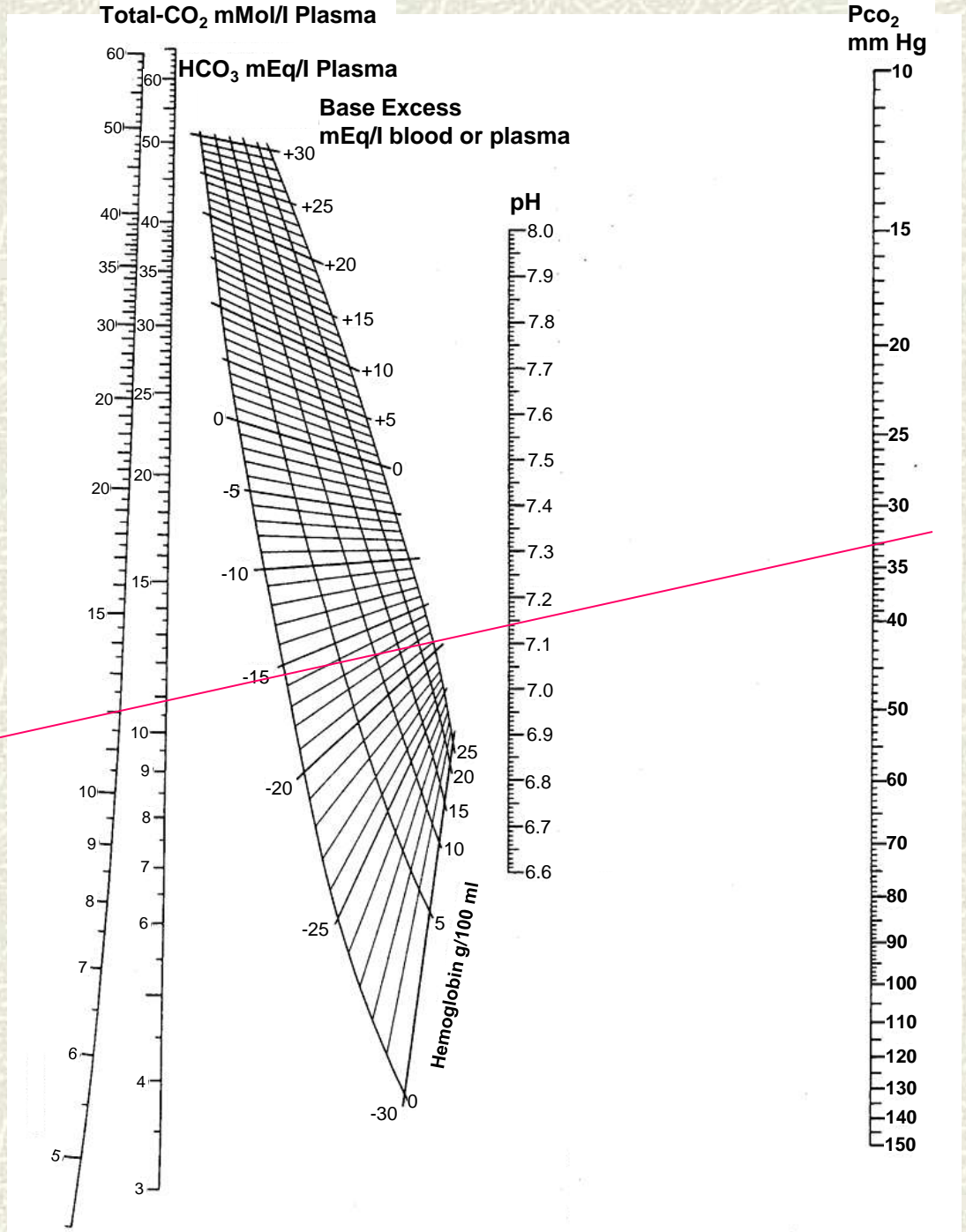
Nomograms

Hesselbach Henderson equation

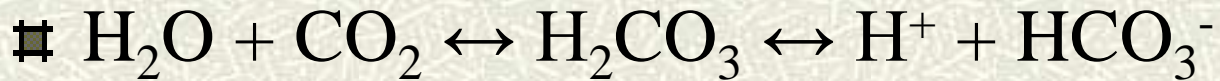
Siggaard Andersen Nomogram

pH and PCO₂

BE, SBE, HCO₃, TCO₂



Hasselbach-Henderson equation



$\text{pH} = \text{pKa} + \log (\text{base } (\text{HCO}_3) / \text{acid } (\text{CO}_2))$

Since 2 values known

pH and pCO₂ given by machine

HCO₃ derived by machine

This HCO₃ value is dependent on the pCO₂ of the patient


Metabolic component

3 values in an ABG show pure metabolic values (independent of $p\text{CO}_2$)

SBC (standard bicarbonate)

ABE (actual base excess)

BE_{ecf} (extra-cellular base excess)



Standard bicarbonate (SBC)*

20-24 m Eq/L

Concentration of HCO_3^- in the blood which has been calibrated to a pCO_2 of 40 mmHg at 37°C

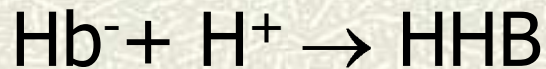
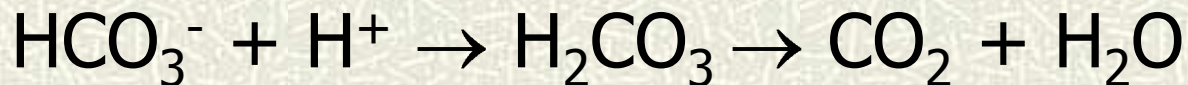
* Represents pure metabolic component with no respiratory effect

Buffer base (BB)

48-50 m mol/L

Buffers in blood

Hemoglobin (25%), bicarbonate (50%) and protein (25%) [i.e. 12 + 24 + 12]



Buffers in Extravascular space

No hemoglobin; only bicarbonate and protein

Base excess

- # Calculated using standard bicarbonate and Hb value (proteins as a constant)
- # 2 calculated values
 - Actual base excess
 - Standard base excess
- # Normal value 3



Actual base excess (ABE)

- # ABE refers to base status of whole blood
- # Calculates using 2 variables
 - Hb
 - Bicarbonate
- # Refers to base excess/ deficit in variance from total buffer base
 - low bicarb means base deficit

Standard base excess (SBE)

- # SBE refers to base status of whole ECF
- # Calculates using 2 buffers
 - Hb assumed to be 5 g/dl (blood and ecf)
 - Bicarbonate
- # Again shows a pure metabolic component with no respiratory effect

Total CO₂ content (TCO₂) 23-27 mmol/L

Venous blood : 2-3 mmol/L↑

$$\begin{aligned} \text{TCO}_2 &= \text{Dissolved CO}_2 + \text{CO}_2 \text{ derived from} \\ &\quad \text{H}_2\text{CO}_3 \\ &= 0.03 \times p\text{CO}_2 + \text{HCO}_3^- \end{aligned}$$



Normal Values

- # pH 7.35 to 7.45
- # pCO₂ 35 to 45 mm Hg
- # HCO₃ 20 to 24 meq/L



ABG Interpretation

- # First, does the patient have an acidosis or an alkalosis
 - # Second, what is the primary problem – metabolic or respiratory
 - # Third, is there any compensation by the patient
-



ABG Interpretation

- # It would be extremely unusual for either the respiratory or renal system to overcompensate
- # The pH determines the primary problem
- # After determining the primary and compensatory acid/base balance, evaluate the effectiveness of oxygenation

Abnormal Values

pH < 7.35

- ▣ Acidosis (metabolic and/or respiratory)

paCO₂ > 45 mm Hg

- ▣ Respiratory acidosis (alveolar hypoventilation)

St HCO₃ < 20 meq/L

- ▣ Metabolic acidosis

pH > 7.45

- ▣ Alkalosis (metabolic and/or respiratory)

paCO₂ < 35 mm Hg

- ▣ Respiratory alkalosis (alveolar hyperventilation)

St HCO₃ > 24meq/L

- ▣ Metabolic alkalosis

Putting It Together - Acidosis

pH < 7.35 with a $p\text{CO}_2 > 45$ represents a respiratory acidosis

pH < 7.35 with a $\text{HCO}_3 < 20$ represents a metabolic acidosis

If both are present, then combined respiratory and metabolic acidosis

Putting It Together - Alkalosis

pH $>$ 7.45 with a $\text{paCO}_2 < 35$ represents a respiratory alkalosis

pH $>$ 7.45 with a $\text{HCO}_3 > 24$ represents a metabolic alkalosis

If both are present, then combined respiratory and metabolic alkalosis

Compensation

#The body's attempt to return the acid/base status to normal (i.e. pH closer to 7.4)

Primary Problem

resp acidosis ($\uparrow\text{CO}_2$)

resp alkalosis ($\downarrow\text{CO}_2$)

Compensation

meta alkalosis ($\uparrow\text{HCO}_3$)

meta acidosis ($\downarrow\text{HCO}_3$)

In compensation, CO_2 and HCO_3 move in the same direction



Useful rules


- # When CO_2 and HCO_3 are in opposite direction think of combined disorder
 - # When CO_2 and HCO_3 are in same direction think of compensation
-



Useful rules

- # For 10 mmHg change in $p\text{CO}_2$, pH changes by 0.08 in opposite direction

- # For 10 meq/l change in HCO_3 , pH changes by 0.15 in same direction

- 
- # Acute res acidosis-10mm of Hg increase in pco₂ – 1 increase in Hco₃ con.
 - # Acute res alkalosis-10mm of Hg decrease in pco₂_ 2 decrease in Hco₃ con.
 - # Chronic res acidosis-10mm of Hg increase in pco₂ – 4 increase in Hco₃ con.
 - # chronic res alkalosis-10mm of Hg decrease in pco₂_ 4 decrease in Hco₃ con.



Metabolic acidosis- $p_{CO_2}=(1.5 \times HCO_3)+8$

Metabolic alkalosis-10mEq/L increase in HCO_3 , p_{CO_2} increases by 7mm of Hg.



ABG 1

pH 7.35

PCO₂ 42

HCO₃ 23

SBE -2

PaO₂ 60

A-1: normal pH, PCO₂ and HCO₃: normal ABG



ABG 2

pH 7.22

PCO₂ 55

HCO₃ 21

SBE -4

PaO₂ 58

A-2 pH – acidosis, PCO₂ high : Resp. acidosis, HCO₃ normal



ABG 3

pH 7.49

PCO₂ 30

HCO₃ 22

SBE 0

PaO₂ 65

A-3 pH- alkalosis, PCO₂ low: Resp alkalosis: HCO₃ normal

ABG 4

pH 7.18

PCO₂ 40

HCO₃ 16

SBE -10

PaO₂ 55

A-4 pH – acidosis, PCO₂ normal, HCO₃ low: metabolic acidosis

Interpretation of ABG

	pH	pCO ₂	BE	HCO ₃	pO ₂
A-1	7.20	50	-10	16	60
A-2	7.28	55	+4	28	58
A-3	7.33	30	-8	16	65

- A-1: pH – acidosis: pCO₂ high- resp acidosis, respiratory and
HCO₃ low: metabolic acidosis also metabolic acidosis
- A-2: pH- acidosis: PCO₂ high : resp acidosis respiratory acidosis with
HCO₃ high : metabolic alkalosis metabolic compensation
- A-3 pH –acidosis: pCO₂ low: resp alkalosis metabolic acidosis with resp
HCO₃ low: metabolic acidosis compensation

Metabolic Acidosis: Anion gap

- # $(\text{Na} + \text{K}) = (\text{HCO}_3 + \text{Cl} + \text{proteins})$
- # Difference of $(\text{Na} + \text{K})$ and $(\text{HCO}_3 + \text{Cl})$ is called anion gap
- # Normal anion gap is 5-12 mmol/L


$$(\text{Na} + \text{K}) = (\text{HCO}_3 + \text{Cl} + \text{proteins})$$

Normal anion gap

Due to loss of bicarb

Compensates by $\uparrow \text{Cl}$ ($\downarrow \text{HCO}_3$ and $\uparrow \text{Cl}$)

So anion gap remains normal

E.g. diarrhea, RTA

Increased anion gap

Addition of strong acids

No compensation by Cl ($\downarrow \text{HCO}_3$ and $\downarrow \text{Cl}$)

So increased anion gap

E.g. lactic, ketoacidosis, salicylate, renal failure



Metabolic Acidosis

Elevated Anion Gap

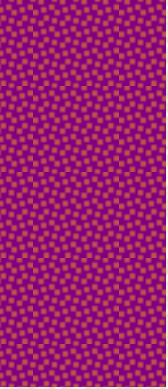
Causes

Ketoacidosis - diabetic, alcoholic, starvation

Lactic acidosis - hypoxia, shock, sepsis, seizures

Toxic ingestion – salicylates, methanol, ethylene glycol, ethanol, isopropyl alcohol, paraldehyde, toluene

Renal failure - uremia



Metabolic Acidosis

Normal Anion Gap

Causes

Diarrhea

Renal tubular acidosis

Post respiratory alkalosis

Hypoaldosteronism

Potassium sparing diuretics

Pancreatic loss of bicarbonate

Summary

- # First, does the patient have an acidosis or an alkalosis

 - Look at the pH (acidosis or alkalosis)

- # Second, what is status of CO_2 and HCO_3

 - Look at the pCO_2 (acidosis or alkalosis)

 - Look at the HCO_3 (acidosis or alkalosis)

Summary

- Third, is it a combined disorder or is there any compensation by the patient

(Resp)	(Metabolic)		
Acidosis	+ acidosis	=	combined
Alkalosis	+ alkalosis	=	combined
Acidosis	+ alkalosis	=	compensation
Alkalosis	+ acidosis	=	compensation



Summary

- # Next, don't forget to look at the effectiveness of oxygenation, (and look at the patient)

- # Diagnose the metabolic disorder (anion gap)



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Spot the diagnosis

CLD on Furosemide, salbutamol

pH 7.51

pCO₂ 45

pO₂ 68

HCO₃ 38

Interpret the ABG

Baby limp required resuscitation with RDS

pH 7.62

pCO₂ 60

pO₂ 76

HCO₃ 48

Referred by your friend from district hospital



Thank you

