Blood Gases

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BENDIGO HEALTH ED REGISTRAR

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Interpretation of blood gases

- Acid base balance
  - pH, CO2, HCO3
  - Major disturbance
  - Compensation
  - Metabolic acidosis
    - Anion gap
    - Delta ratio
- Oxygenation
- Other electrolytes

Arterial Blood Gas Analysis

ABG Parameter			ABG result
pH	>7.45	Alkalaemia	
	7.36-44	Normal	
	<7.35	Acidaemia	
pCO2	>45	High	
	35-45	Normal	
	<35	Low	
HCO3	>26	High	
	24+/- 2	Normal	
	<22	Low	
AG	> 16	High	
	12+/-4	Normal	
	< 8	Low	
Glucose	>10	High	
	< 2	Low	
Gap: Gap	$\frac{\Delta \text{ AG}}{\Delta HCO_3} = \frac{\text{AG - 12}}{\text{24 - } HCO_3}$		
Lactate	**<1.9**	Normal	
	>2.0	High	
pO2	80-100	Normal	
	< 80	Hypoxia	

Calculation and interpretation		
pH	**pCO2**	**Interpretation**
↓	↓	Metabolic acidosis
↑	↑	Metabolic alkalosis
↑	↓	Respiratory alkalosis
↓	↑	Respiratory acidosis

Corrected standard AG for albumin

$$\frac{\text{Albumin}}{4} + 1.5 \times \text{Phosphate}$$

Anion Gap calculation

$$\{[Na+] - [Cl^- + HCO_3]\} = 12+/-4$$

Corrected Na+ for AG in hyperglycemia

$$\text{Corrected Na+} = \text{Na} + \frac{\text{Glucose} - 5}{3}$$

Gap: Gap calculation for metabolic acidosis

<0.4	Low or Normal AG metabolic acidosis
0.4-0.8	Normal + high AG metabolic acidosis
0.8-2.0	Pure high metabolic acidosis
>2.0	Metabolic acidosis with metabolic alkalosis/respiratory acidosis

PAO2 = [713 x FiO2] – [pCO2 x 1.25]

A-a gradient = PAO2 – PaO2 = $\frac{\text{Age}}{4} + 4$

Compensation rules for

	Metabolic acidosis	Metabolic alkalosis
Expected PCO2	1.5 X [HCO3] + 8 (+/- 2)	0.7 X [HCO3] + 20 (+/- 5)

	Respiratory acidosis		Respiratory alkalosis	
	Acute	Chronic	Acute	Chronic
Expected HCO3	$24 + \frac{pCO2 - 40}{10} \times 1$	$24 + \frac{pCO2 - 40}{10} \times 4$	$24 - \frac{40 - pCO2}{10} \times 2$	$24 - \frac{40 - pCO2}{10} \times 5$

Acid Base Balance

- pH
  - Normal 7.35-7.45
  - Alkalaemia >7.45
  - Acidaemia <7.35
- pCO2
  - Normal 35-45
  - High >45
  - Low <35
- HCO3
  - Normal 24 +/- 2
  - High >26
  - Low <22

Major Disturbance

Major Disturbance

	pH	CO2	HCO3
Metabolic acidosis	↓		↓
Respiratory acidosis	↓	↑	
Metabolic alkalosis	↑		↑
Respiratory alkalosis	↑	↓	

- 63f with dyspnoea

- pH 7.29
- PCO2 68
- HCO3 26

- Acidaemia
- Hypercarbia
- Normal HCO3

- **Respiratory acidosis**

- 17f chest tightness, dyspnoea, perioral tingling, upper limb paraesthesias

- pH 7.49
- PCO2 24
- HCO3 22

- Alkalaemia
- Hypocarbia
- Normal HCO3

- **Respiratory alkalosis**

- 48m distended abdo + vomiting. CT shows bowel obstruction

- pH 7.5
- PCO2 41
- HCO3 29

- Alkalaemia
- Normal CO2
- High HCO3

- **Metabolic alkalosis**

- 89f confusion, fevers, rigors, hypotension, oliguria

- pH 7.29
- PCO2 41
- HCO3 15

- Acidaemia
- Normal CO2
- Low HCO3

- **Metabolic acidosis**

Compensation

Expected PCO2

- Metabolic acidosis
  - 1.5x HCO3 + 8 (+/-2)
  - *Winter's equation*
- Metabolic alkalosis
  - 0.7x HCO3 + 20 (+/-5)

Expected HCO3

	HCO**3** (baseline 24mmol/L)	
Every **10mmHg** change in PCO2 from baseline 40mmHg	Acute	Chronic
Increased PCO2 (resp acidosis)	**1**	**4**
Decreased PCO2 (resp alkalosis)	**2**	***5***

- 56m found by bystanders with GCS7 and pinprick pupils. Naloxone administered by paramedics

- pH 7.31
- PCO2 55
- HCO3 27

- Acidaemia
- Hypercarbia
- High HCO3 Major disturbance?
- Expected HCO3
  - Acute 26
  - Chronic 30

- **Acute respiratory acidosis with metabolic compensation**

- 77f 10/7 post #NOF with hypoxia and tachypnoea

- pH 7.51
- PCO2 23
- HCO3 21

- Alkalaemia
- Hypocarbia
- Low HCO3 Major disturbance?
- Expected HCO3
  - Acute 20
  - Chronic 14

- **Acute respiratory alkalosis with metabolic compensation**

- 24m medical student returned from elective in Nepal. Few days severe diarrhoea with dehydration and tachypnoea

- pH 7.32
- PCO2 30
- HCO3 13

- Acidaemia
- Hypocarbia
- Low HCO3 Major disturbance?
- Expected CO2
  - 1.5x13+8 = 28

- **Metabolic acidosis with respiratory compensation**

- 34f presents with vomiting after binge drinking last night

- pH 7.46
- PCO2 52
- HCO3 39

- Alkalaemia
- Hypercarbia
- High HCO3 Major disturbance?
- Expected CO2
  - 0.7xHCO3 +20 (+/-5) = 47 (+/-5)

- **Metabolic alkalosis with respiratory compensation**

- 27m footballer completing pre-season training in Colarado at high altitude

- pH 7.47
- PCO2 20
- HCO3 14

- Alkalaemia
- Hypocarbia
- Low HCO3 Major disturbance?
- Expected HCO3
  - Acute 22
  - Chronic 14

- **Chronic respiratory alkalosis with metabolic compensation**

- 64 y/o male
- End stage COPD
- Currently smoking
- 3/7 worsening dyspnoea

BLOOD GAS ANALYSIS **SPECIMEN: BLOOD**

Date:		**19/08/20**		19/08/20		19/08/20				
Coll. Time:		17:04		16:02		14:38				
Lab Number:		43472555		43472552		43472648	Ref. Range		Unit	
Blood Type		**Venous**		**Venous**		**Venous**				
Temperature		37.5		37.0		37.0				
pH	**	**7.22**	**	**7.24**	*	**7.31**	(7.35 - 7.45)			
pCO2	***	**111**	***	**104**	***	**84**	(35 - 46)		mm Hg	
pO2	*	**39**	*	**38**	*	**27**	(80 - 100)		mm Hg	
T corr pH	**	**7.21**	**	**7.24**	*	**7.31**	(7.35 - 7.45)			
T corr pCO2	***	**113**	***	**104**	***	**84**	(35 - 46)		mm Hg	
T corr pO2	*	**40**	*	**38**	*	**27**	(80 - 100)		mm Hg	
HCO3	***	**45**	***	**45**	***	**42**	(21 - 28)		mmol/l	
Base Ex	*	**12.2**	*	**12.0**	*	**11.5**	(-2 - +3)		mmol/l	
sO2	*	**66.2**	*	**61.3**	*	**44.9**	(95.0 - 100.0)%			
Sodium		139		138		135	(135 - 145)		mmol/L	
Potassium		4.4		4.3		4.2	(3.4 - 4.8)		mmol/L	
Chloride		97		96		96	(95 - 110)		mmol/L	
Anion Gap	*	**1**	*	**2**	*	**1**	(8 - 20)		mmol/L	
Ionised Ca		1.18		1.17	*	1.11	(1.15 - 1.35)		mmol/L	
Glucose		6.9	*	**8.3**	*	**10.2**	(3.0 - 6.9)		mmol/L	
L-Lactate		1.1		1.3	*	**1.7**	(< 1.5)		mmol/L	
Haemoglobin		148		150		157	(120 - 180)		g/L	
Haematocrit		44		45		47	(35 - 51)		%	
O2Hb	*	**63.1**	*	**58.4**	*	**43.1**	(> 95.0)		%	
COHb	*	**3.4**	*	**3.0**	*	**2.9**	(< 2.0)		%	
MetHb		1.2		1.7		1.2	(< 3.0)		%	
HHb	*	**32.2**	*	**36.9**	*	**52.9**	(< 5.0)		%	
FIO2		25							%	

- Acidaemia
- Hypercarbia
- High HCO3 Major disturbance?
- Expected HCO3
  - Acute 28
  - Chronic 40
- **Chronic respiratory acidosis with metabolic compensation**
- Following deterioration?
- **Acute on chronic respiratory acidosis with metabolic compensation**

- 64m chest pain, arrests soon after arrival receiving 6min CPR and regaining ROSC

- pH 7.14
- PCO2 60
- HCO3 15

- Acidaemia
- Hypercarbia
- Low HCO3 Major disturbance?

- **Respiratory acidosis and metabolic acidosis**

Metabolic acidosis – Anion gap

- $(Na^+ + K^+) + (Cl^- + HCO3^-)$
- Anion Gap
  - Normal 12 +/- 4
  - High >16
  - Low <8

High Anion Gap Metabolic Acidosis – Delta Ratio

- $$\frac{\Delta AG}{\Delta HCO3} = \frac{AG - 12}{24 - HCO3}$$

Delta Ratio	
<0.4	NAGMA
0.4-0.8	NAGMA + HAGMA
0.8-2	HAGMA
>2	Metabolic acidosis + metabolic alkalosis

- 23m T1DM presents following fist fight with his brother. Missed insulin dose that morning due to stress

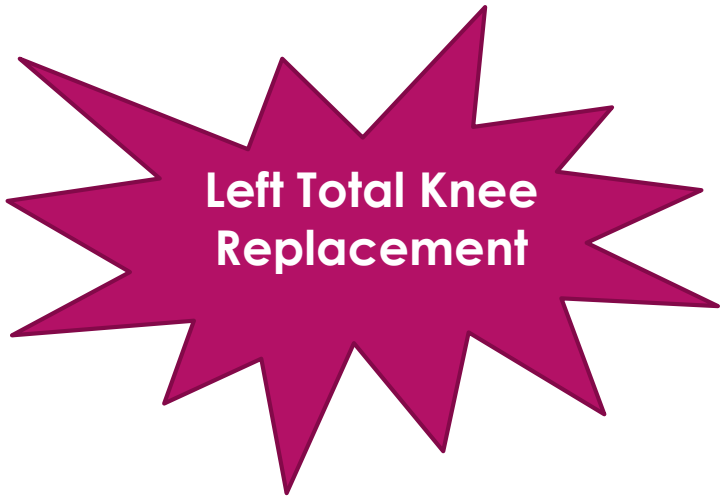
BLOOD GAS ANALYSIS **SPECIMEN: BLOOD**

Date:		**19/08/20**		19/08/20		19/08/20		
Coll. Time:		18:07		16:43		15:07		
Lab Number:		43472559		43472554		43472649	Ref. Range	Unit
Blood Type		**Venous**		**Venous**		**Venous**		
Temperature		37.0		37.0		37.0		
pH	*	**7.32**	*	**7.25**	**	**7.18**	(7.35 - 7.45)	
pCO2	*	**31**	**	**29**	*	**31**	(35 - 46)	mm Hg
pO2	*	**70**	*	**63**	*	**28**	(80 - 100)	mm Hg
T corr pH	*	**7.32**	*	**7.25**	**	**7.18**	(7.35 - 7.45)	
T corr pCO2	*	**31**	**	**29**	*	**31**	(35 - 46)	mm Hg
T corr pO2	*	**70**	*	**63**	*	**28**	(80 - 100)	mm Hg
HC03	**	**16**	***	**13**	***	**12**	(21 - 28)	mmol/l
Base Ex	*	**-8.9**	*	**-13.1**	*	**-15.5**	(-2 - +3)	mmol/l
sO2		95.7	*	**93.5**	*	**61.2**	(95.0 - 100.0)	%
Sodium	*	**133**	*	**131**	**	**129**	(135 - 145)	mmol/L
Potassium		3.8		3.8		4.6	(3.4 - 4.8)	mmol/L
Chloride		106		104		98	(95 - 110)	mmol/L
Anion Gap		15		18	*	**24**	(8 - 20)	mmol/L
Ionised Ca	*	1.09	*	1.09	*	1.11	(1.15 - 1.35)	mmol/L
Glucose		5.2	*	**7.1**	*	**18.0**	(3.0 - 6.9)	mmol/L
L-Lactate		0.8		1.3	*	**1.8**	(< 1.5)	mmol/L
Haemoglobin		140		141		152	(120 - 180)	g/L
Haematocrit		42		42		46	(35 - 51)	%
O2Hb	*	**91.8**	*	**89.8**	*	**58.9**	(> 95.0)	%
COHb	*	**2.6**	*	**2.7**	*	**2.2**	(< 2.0)	%
MetHb		1.5		1.3		1.5	(< 3.0)	%
HHb		4.1	*	**6.2**	*	**37.4**	(< 5.0)	%

- Acidaemia
- Hypocarbia
- Low HCO3 Major disturbance?
- Expected CO2: 26
- AG = $(Na^+ + K^+) - (Cl^- + HCO3^-) = 23$
- Δ ratio = $\frac{AG - 12}{24 - HCO3} = 0.9$
- **HAGMA with incomplete respiratory compensation**

Causes of HAGMA

- Lactate
  - Hypoperfusion
  - Medical problems
    - Sepsis
    - Liver failure
  - Drugs
    - Metformin
    - iron
  - Inborn errors of metabolism
- Toxins
  - Salicylates
- Ketones
  - DKA
  - ETOH
  - Starvation
- Renal failure
  - Urea



Causes of NAGMA

- **Hyperchloraemia**
- **Addison's disease**
- Drugs
  - Carbonic anhydrase inhibitors eg. **Acetazolamide**
  - Spironolcatone
- HCO3 loss
  - **Renal Tubular Acidosis**
  - Excessive **Diarrhoea**
  - Fistulas
    - **Uretoenteric**
    - **Pancreaticoduodenal**

Respiratory Acidosis

- Hypoventilation
- "Won't breathe, can't breathe, can't breathe enough"
- "Won't breathe" – central causes
  - OD
  - Traumatic brain injury
  - CVA
- "Can't breathe" – neuromuscular
  - GBS
  - Envenomation
- "Can't breathe enough" – primary respiratory pathology
  - Obstruction
  - COPD
  - Asthma
  - Lung insults
    - Trauma
    - Lung membrane diseases eg. Pulmonary oedema, LRTI, ARDS, aspiration
- Acute vs Chronic

Respiratory alkalosis

- Hyperventilation
- Hypoxaemia
  - Altitude
  - PE
  - Pneumonia
  - Asthma
  - Pulmonary oedema
- Central
  - Voluntary or psychogenic (anxiety, pain)
  - CVA
  - Increased ICP (tumour, ICH, trauma)
- Tox
  - Salicylates
  - Caffeine, nicotine
  - Sympathomimetics
  - Thyroxine
- Increased metabolic state eg. pregnancy

Metabolic Alkalosis

- H+ loss
  - HCl loss
    - Vomiting
  - Drugs
    - Diuretics eg. Frusemide
    - Laxative abuse
- Alkali gain
  - NaHCO3 therapy
- Impairment of kidney's ability to excrete HCO3
  - Cl depletion
  - K depletion
    - Endocrinopathies
      - Cushing's
      - Bartter's
  - Decreased GFR
  - ECF volume depletion

Assess Oxygenation

- ABG
- Aa gradient

  = PAO2 – PaO2

  $= \frac{\text{age}}{4} + 4$

- PAO2

  = ((760 – vapour pressure) x FiO2) – (paCO2 x 1.25)

  = (713 (sea level) x FiO2) – (paCO2 x 1.25)

  = 150mmHg (sea level, room air) – (paCO2 x 1.25)

Check other electrolytes

- Na
  - Correct sodium for glucose eg DKA
  - Corrected Na = Na + $\frac{\text{glucose} - 5}{3}$
- K
  - Correct potassium for pH
  - For each 0.1 fall in pH K should rise by 0.5mmol above 5.0mmol/L
  - For each 0.1 rise in pH K should fall by 0.5mmol below 5.0mmol/L
- Cl
- Glucose
- Osmolality
  - 2x Na + urea + glucose
  - Osmolar gap = measured osmolarity – calculated osmolality

Interpretation of blood gases

- Acid base balance
  - pH, CO2, HCO3
  - Major disturbance
  - Compensation
  - Metabolic acidosis
    - Anion gap
    - Delta ratio
- Oxygenation
- Other electrolytes