WESTMEAD EMERGENCY MEDICINE

The University of Sydney

Blood Gases Workshop 2021

Dr Andrew Coggins FACEM

Westmead Hospital Staff Specialist Emergency Medicine and In-patient Trauma

(Credits LITFL, WICM, Creative Commons)

Background

- Shortness of Breath is a common ED presentation and admission "*main complaint*"
- Respiratory Failure
  - leading cause of ICU admission
- Septic Shock
  - leading cause of mortality

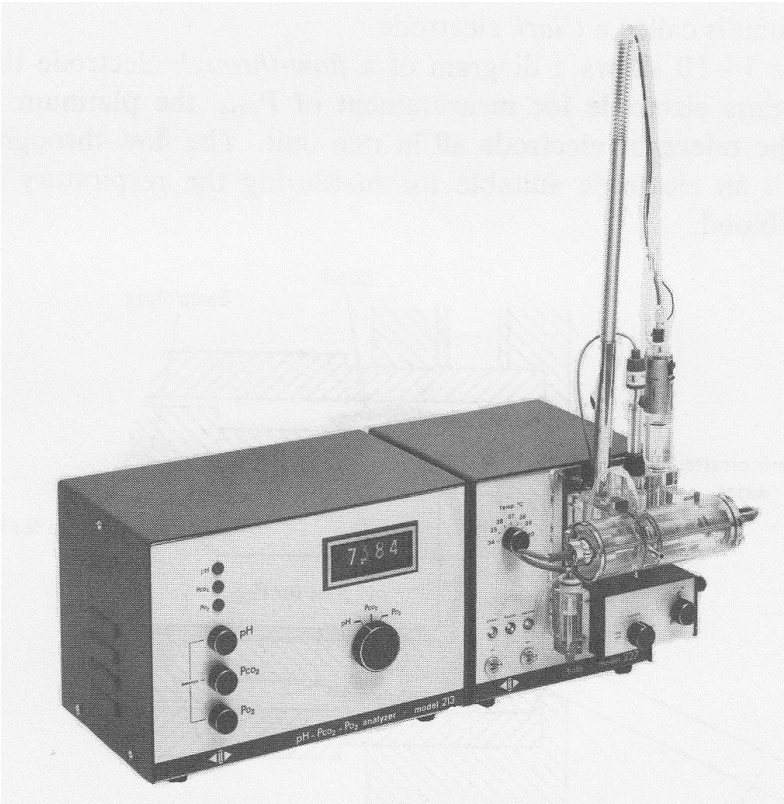
Agenda - Blood Gases Workshop

- Rationale, History,Types of Blood Gas
- Basic Rules Recap
- Advanced Rules
- Case Based Learning

The University of Sydney

Overview

- Historical Context



Why take a blood gas?

- Sudden dyspnea
- Cyanosis
- Abnormal breath sounds
- Sudden or unexplained tachypnea
- Heavy use of accessory muscles
- Change in ventilator setting
- CPR
- Diffuse infiltrates in c xray

Contraversy

- What do you think about using a "*venous blood gas*"?

pH

- Good correlation
- pooled mean difference: +0.035 pH units

pCO2

- Good correlation in normocapnia
- Non-correlative in severe shock
- 100% sensitive in screening for arterial hypercarbia in COPD exacerbation using cut points of PaCO2 45 mmHg (6KPA) and lab testing (McCanny et al, 2012)

Bicarbonate

- Good correlation
- Mean difference −1.41 mmol/L (−5.8 to +5.3 mmol/L 95%CI)

Lactate

- Poor correlations above 2 mmol/L
- Mean difference 0.08 (-0.27 – 0.42 95%CI)

Base Excess

- Good correlation
- Mean difference 0.089 mmol/L (–0.974 to +0.552 95%CI)

Oxygen

- PO_2 values compare poorly
- arterial PO_2 is typically 36.9 mmHg greater than the venous with significant variability

Clinical Scenarios suited to VBG

- Diabetic Emergencies – i.e. DKA, HHS
- Septic Screening
- Monitor (Hyponatraemia, HB monitoring)
- Possibly Trauma
- ?Others
  - *When might you use this in your practice?*

ABG required if…

- Accurate measurement of $PaCO_2$ in shock
- Accurate measurement of $PaCO_2$ if hypercapnic (i.e. $PaCO_2$ >45 mmHg)
- Accurate Lactate
- PO_2 for planning (Electively)
- PO_2 acutely is saturations problematic
- Equivocal Cases

The University of Sydney

AUDIT at our centre - *Utilisation of point of care blood gases within 4-hours of ED arrival in trauma patients (ISS≥12)*

Recorded blood gas sampling <4h of ED presentation	**n/%**	**30-day Mortality**
No ABG or VBG performed	83 (18.2%)	2 (2.4%)
VBG only performed	243 (53.4%)	23 (9.5%)
ABG only performed	63 (13.8%)	9 (14.2%)
ABG and VBG performed	12 (2.6%)	1 (8.3%)
** (ABG and VBG performed)*	**54 (11.9%)*	*4 (7.4%)*

OUR TRAUMA DATA (N=176)

Table 2 Comparison of paired ABG and venous blood gas samples (n=176)

Blood gas parameters (variable)	Valid sample values (n)	Pearson correlation between arterial and venous samples	Average (arterial and venous)		Arterial minus venous		P value (t-test of zero bias)	Limits of agreemen (LOA)[21]	
			Median	Range	Mean difference (estimated bias)	SD difference		Lower	Upper
pH	175	0.858	7.36	7.02, 7.59	0.036	0.042	<0.001	−0.048	0.120
Base deficit (mmol/L)	176	0.877	−0.43	−16.5, 5	−1.27	1.54	<0.001	−4.35	1.81
Lactate (mmol/L)	169	0.931	1.90	0.55, 14.7	−0.64	0.61	<0.001	−1.86	0.57
HCO_3 (mmol/L)	175	0.848	24.5	11, 35	−1.97	1.76	<0.001	−5.49	1.55
Hb (g/dL)	172	0.899	139	88.5, 177	−4.69	7.46	<0.001	−19.61	10.23
Sodium (mmol/L)	169	0.886	139.5	129, 147	−1.08	1.36	<0.001	−3.80	1.64
Potassium (mmol/L)	170	0.683	3.9	2.9, 6.9	−0.19	0.50	<0.001	−1.19	0.81
Ionised calcium (mmol/L)	168	0.833	1.19	0.95, 1.31	0.000	0.030	0.537	−0.060	0.060
Creatinine (µmol/L)	162	0.980	82.5	37, 277	−6.35	5.50	<0.001	−17.35	4.65
Glucose (mmol/L)	172	0.969	7.2	4.3, 31	0.37	0.77	<0.001	−1.17	1.91
PCO_2 (mm Hg)	175	0.747	44.5	21, 94	−7.59	7.09	<0.001	−21.77	6.59
PO_2 (mm Hg)	171	0.341	71.9	37.6, 483	116.01	113.79	<0.001	−111.57	343.59
O2 Sats (%)	172	0.133	80.43	53.5, 100	36.74	22.45	<0.001	−8.16	81.64

PCO_2, partial pressure of carbon dioxide; PO_2, partial pressure of oxygen.

10.1136/emermed-2020-209751

Typical Blood Gas – 1 minute

Blood Gas Values			
↑ pH	7.451		[7.350 - 7.450]
↑ pCO_2	54.5	mmHg	[35.0 - 45.0]
↓ pO_2	58.3	mmHg	[75.0 - 100]
Acid Base Status			
$cHCO_3^-(P,st)_c$	35.6	mmol/L	
$cBase(Ecf)_c$	12.7	mmol/L	

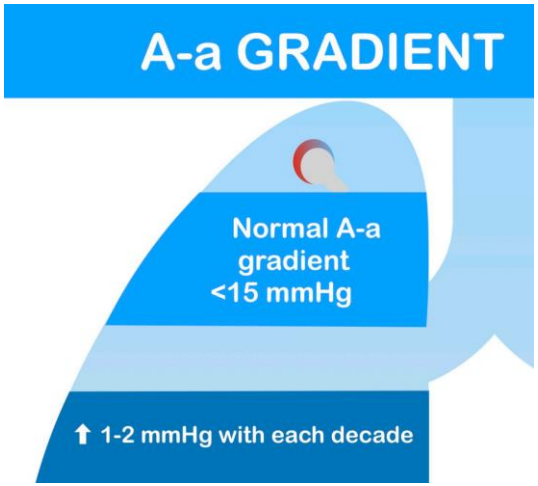
5 Basic Rules – 1 minute ABG

1. How is the patient?

   Ask or look…

2. Is the patient hypoxaemic?

   Is the patient relatively hypoxaemic?*



*Quick Rule of thumb x the Oxygen % by 5

3rd Basic Rules

Is the patient acidotic or alkalotic?

- pH direction generally telling:

If the pH is normal, there must be

- 2 or more problems *(mixed picture)*
- no problem
- pregnant patient *(compensated respiratory alkalosis)*

The University of Sydney

4th and 5th Basic Rules

4. What has happened to the $PaCO_2$

Is the abnormality wholly or partly due to a defect in the respiratory system?

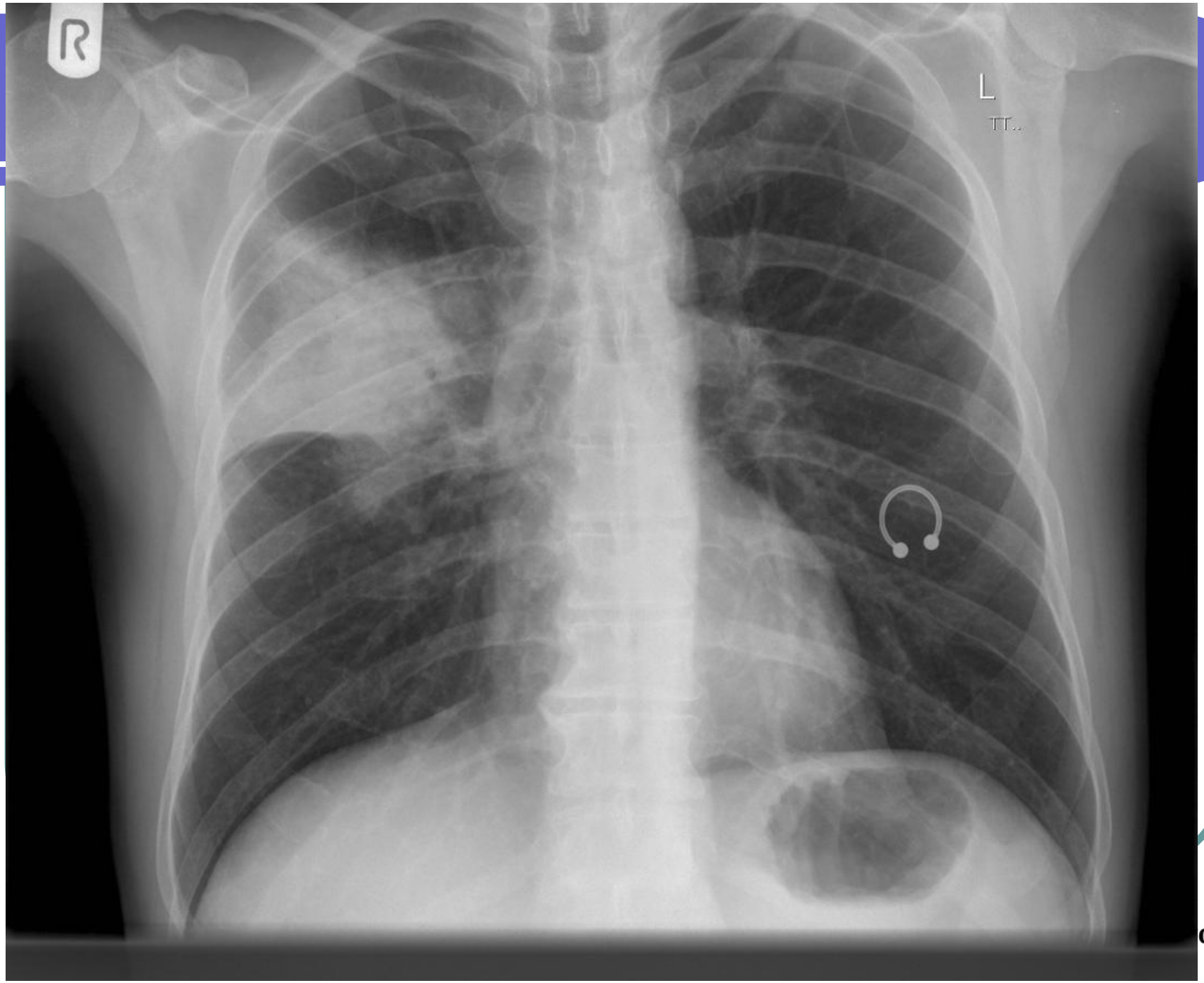
5. What has happened to the base excess and/or bicarbonate?

Is the abnormality wholly or partly due to a defect in the metabolic system?

Scenario 1

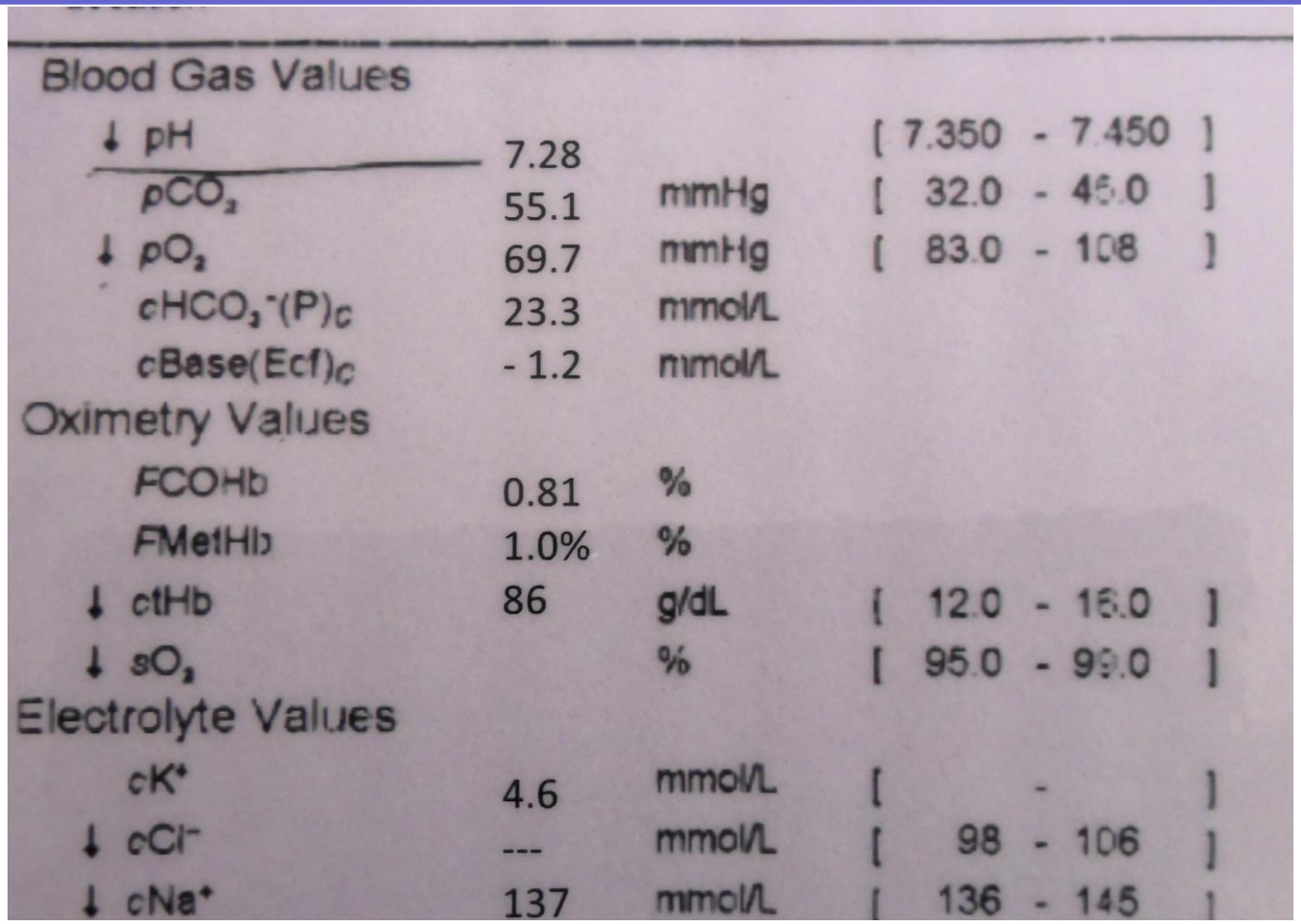
- 48 year old smoker with fever and cough and shortness of breath.
- He has a poor saturations trace and appears unwell
- Blood cultures have been sent and his venous lactate is 5.1mmol
- You wish to determine his O2 and an accurate lactate

(This is his Chest X-ray):



dney

Scenario 1 - ABG



Blood Gas Values			
↓ pH	7.28		[7.350 - 7.450]
pCO_2	55.1	mmHg	[32.0 - 45.0]
↓ pO_2	69.7	mmHg	[83.0 - 108]
$cHCO_3^-(P)_c$	23.3	mmol/L	
$cBase(Ecf)_c$	- 1.2	mmol/L	
Oximetry Values			
FCOHb	0.81	%	
FMetHb	1.0%	%	
↓ ctHb	86	g/dL	[12.0 - 16.0]
↓ sO_2		%	[95.0 - 99.0]
Electrolyte Values			
cK^+	4.6	mmol/L	[-]
↓ cCl^-	---	mmol/L	[98 - 106]
↓ cNa^+	137	mmol/L	[136 - 145]

Scenario 1

- How do you determine severity of his pneumonia?
- What treatment(s) would you recommend

Scenario 2

- **65 year woman with sudden onset right sided chest pain and dyspnoea.**
  - What are the clinical risk factors for Pulmonary Embolus (PE)?
  - What is your current diagnostic approach to confirm or exclude PE?
  - What is the role of D dimer, VQ, CTPA, CXR, ECG, blood gases in diagnosing PE?

Scenario 2 – Blood Gas

- **This is her arterial blood gas (ABG) result on no oxygen (21%)**:
  - pH 7.51, PO2 49, PCO2 27, HCO3 23, Base Excess -1.9
  - How do you interpret this ABG result?

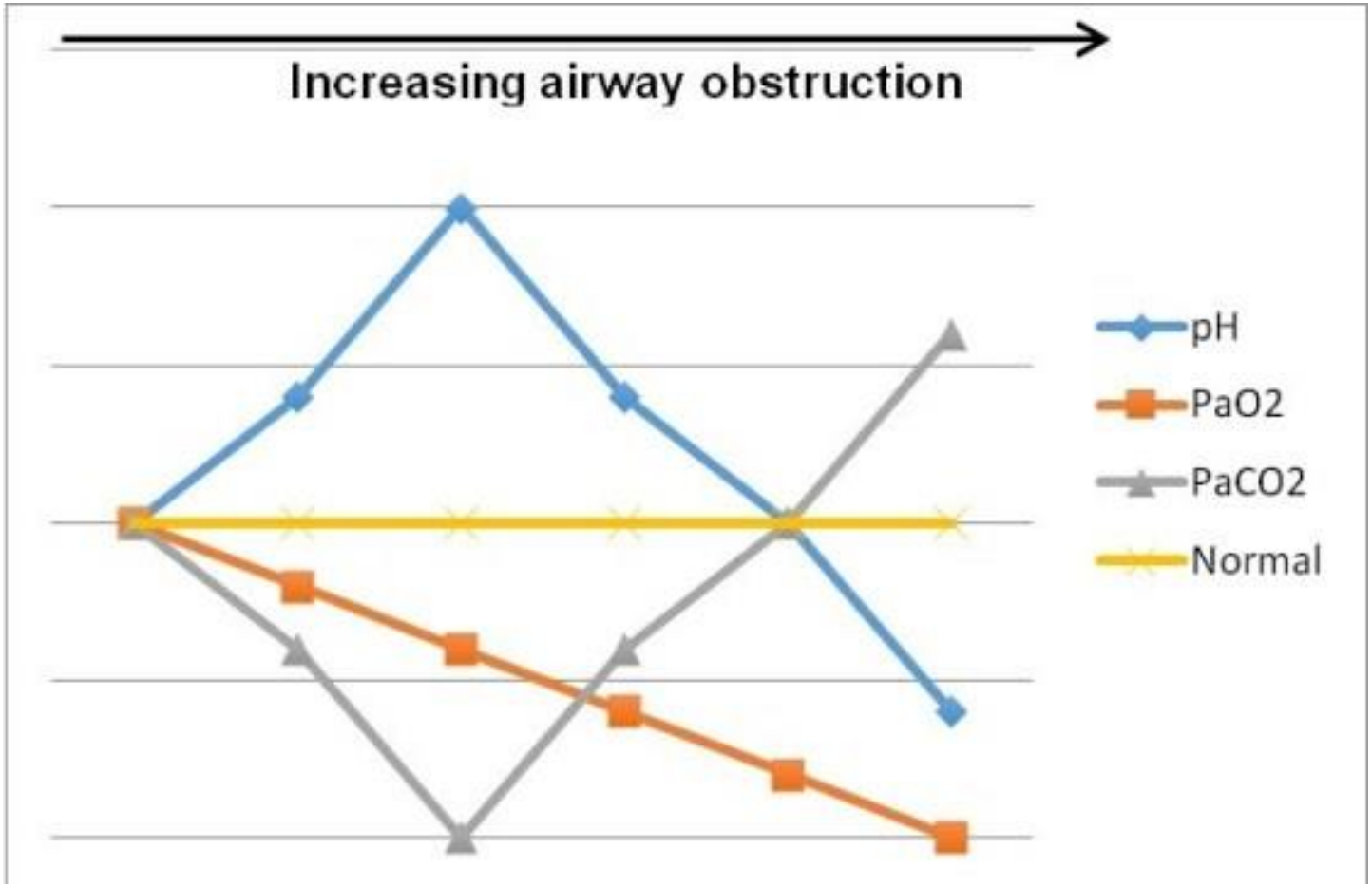
Scenario 3

- **19 year old woman with history of asthma presents with dyspnoea?**
- **Resp Rate 45, HR 140, BP 130/70**
  - How would you assess the severity of her current asthmatic attack?
  - What is the role of a blood gas in Asthma?

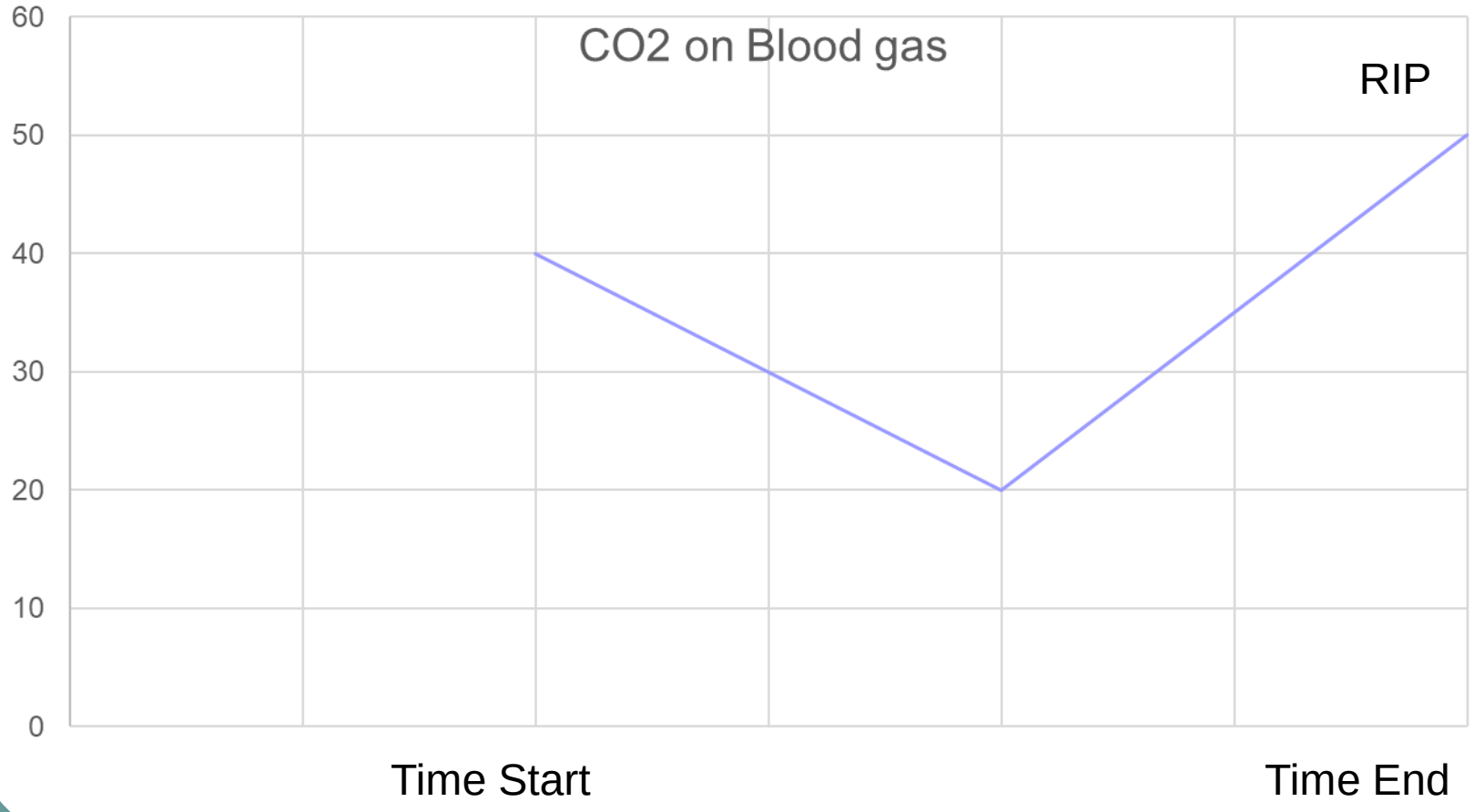
Here is her blood gas (venous)

- pH 7.40
- $PaCO_2$ 42
- PaO_2 150
- Bicarbonate 23
- B/E -1

CO2 in Asthma

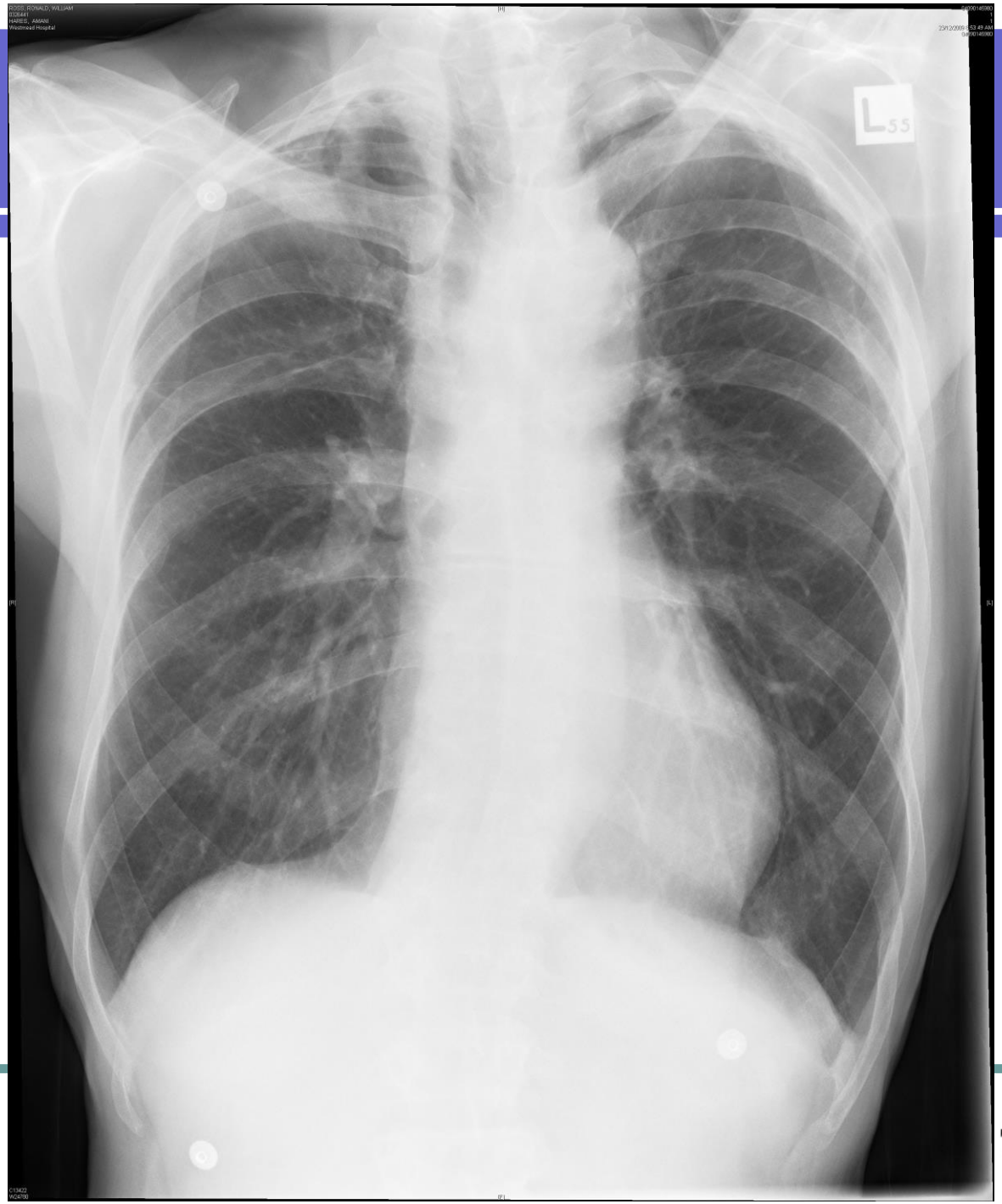


Time v Co2



Scenario 4

- **74 year old man, life-long smoker, with severe respiratory distress and a saturation of 82%.**
  - **This is his Chest X-ray.**



Scenario 4

- What factors could have exacerbated his chronic airway limitation (CAL)?
- How do you manage him initially?

ABG

Blood Gas Values			
↓ pH	7.282		[7.350 - 7.450]
↑ pCO_2	55.1	mmHg	[35.0 - 45.0]
↓ pO_2	69.7	mmHg	[75.0 - 100]
Acid Base Status			
$cHCO_3^-(P,st)_c$	23.3	mmol/L	
$cBase(B)_c$	-1.2	mmol/L	[-3.0 - 3.0]
Electrolyte Values			
cK^+	4.6	mmol/L	[3.4 - 5.5]
cNa^+	137	mmol/L	[136 - 146]
↓ cCa^{2+}	1.08	mmol/L	[1.15 - 1.30]
$cCa^{2+}(7.4)_c$	1.01	mmol/L	
cCl^-	100	mmol/L	[94 - 107]
Metabolite Values			
↑ cGlu	6.0	mmol/L	[3.9 - 5.8]
↑ cLac	2.7	mmol/L	[0.5 - 2.0]

Should we remove the O2

- ?

Practice » Lesson of the Week

Rebound hypoxaemia after administration of oxygen in an acute exacerbation of chronic obstructive pulmonary disease

BMJ 2011 ; 342 doi: https://doi.org/10.1136/bmj.d1557 (Published 31 March 2011)
Cite this as: *BMJ* 2011;342:d1557

Binita Kane, SpR in Respiratory Medicine1, Peter M Turkington, consultant physician in respiratory medicine1,

The University of Sydney

Scenario 5

Rebound Hypoxia - described in BMJ

- Consider well lady with CAL

pH 7.40 c
CO_2 34
O_2 60
Bicarbonate 24

- Develops exacerbation CAL and given 4litres/min NP for days

pH 7,22
CO_2 90
O_2 150mmhg
Bicarbonate 36

- **Oxygen removed**

Oxygen therapy in COPD

- 20 mins after O_2 removed

pH 7.28
CO_2 82
O_2 32 YES 32 !
Bicarb 37

WHY? CO_2 stores are extensive

Put this in your alveolar gas equation
$PAO_2 = FiO_2 (760\text{-}47)) – pCO_2 / R0.8$
147- 102 only 45 at best without considering abnormal lungs
24% would give at best 60 but she has a big a/A gradient

Needed 28% at least to prevent rebound hypoxia

Between the Flags
Keeping patients safe
A statewide initiative of the Clinical Excellence Commission
The University of Sydney

What happened?

- Rebound – Why?
  - Body's CO_2 stores are very large
  - Stop the oxygen, pO_2 drops quickly
- pCO_2 does not, especially if very high – in this case the alveolar oxygen pressure can drop below where it was before O_2 commenced

The **Alveolar Gas Equation**:

$$P_AO_2 = PiO_2 - \frac{P_aCO_2}{0.8}$$

$$PiO_2 = FiO_2 (P_b - P_{H20})$$

The University of Sydney

Oxygen administration

Acute deterioration: hypoxia kills *not* hypercarbia

Chronic (i.e. COPD)

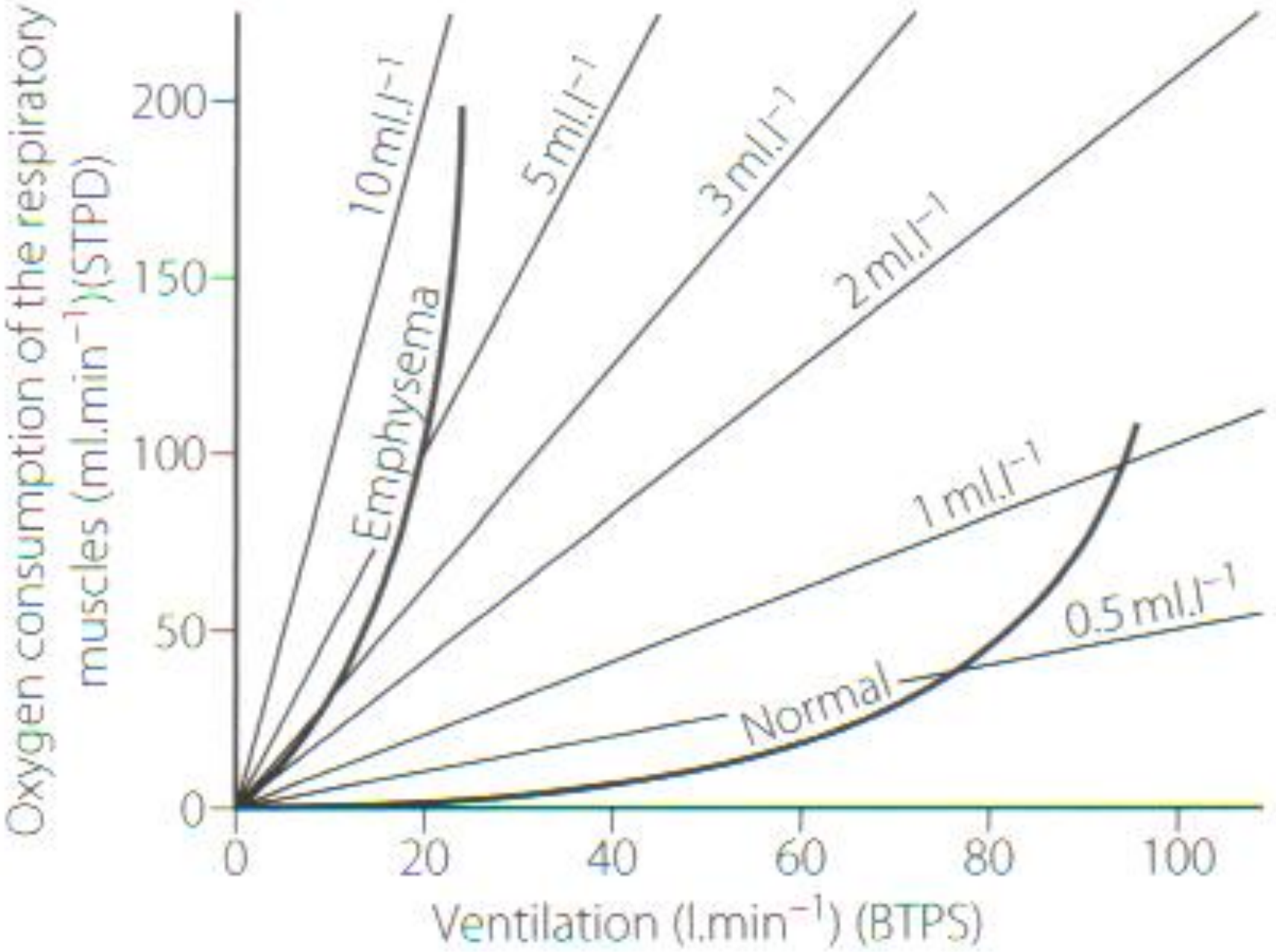
- SaO_2 88-92%
- *Start FiO_2 low*; ↗ O_2 to maintain SaO_2
- Monitor Co_2
- NEVER *abruptly* remove O_2
  Rebound hypoxaemia. BMJ ref

Acute (i.e Asthma)

- SaO2 94-98%
- Hudson 6-8ltr
- Beware ↗ Co_2 = exhaustion HELP
- Do not *abruptly* remove O_2

Severe COPD

- Tachypnoea
- Marked dyspnoea
- Pursed lip breathing
- Use of accessory muscles at rest
- Acute confusion
- New onset cyanosis
- New onset peripheral oedema
- Marked reduction in ADL's

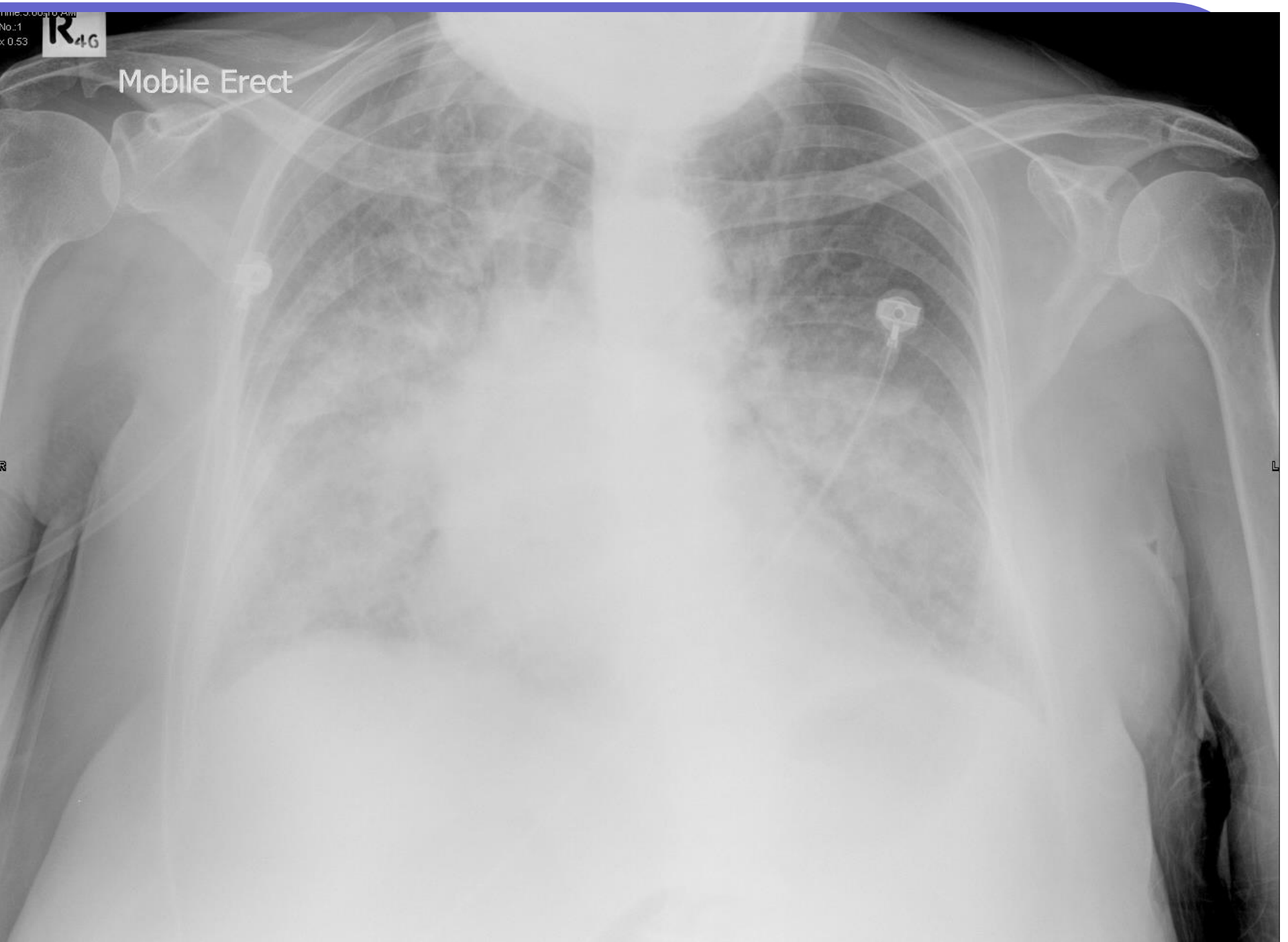

Oxygen consumption of the respiratory muscles (ml.min^{-1})(STPD)
200
150
100
50
0
0
20
40
60
80
100
Ventilation (l.min^{-1}) (BTPS)
10 ml.l^{-1}
5 ml.l^{-1}
3 ml.l^{-1}
2 ml.l^{-1}
1 ml.l^{-1}
0.5 ml.l^{-1}
Emphysema
Normal

COPD

- Up to 25% of patients with a severe unexplained exacerbation of COPD may have a co-existing PE.
  - *Tillie-Lebland, Marquette et al, Annals of Internal Medicine 2006*

Scenario 6

- **67 year old woman in pre planning for dialysis and with severe heart failure is brought in by ambulance at 5am with sudden onset respiratory distress.**
  - **This is her Chest X-ray**


Mobile Erect

Scenario 6

- What are the conflicting issues in managing this patient?
- Please interpret their ABG

What is your interpretation

			Reference range
pH	7.31		(7.35-7.45)
PCO_2	30	mmHg	(35-45)
PO_2	104	mmHg	(75-100)
HCO_3	18.5	mmol/L	(22-33)
BE	-4.8		(-3.0-+3.0)
Saturation	99%		(95-98%)
FIO_2	0.21		
Na^+	141	mmol/L	(135-145)
K^+	8.4	mmol/L	(3.2-4.5)
Ca^{2+}	1.21	mmol/L	(1.15-1.35
Cl^-	113	mmol/L	(100-110)

Advanced Rules

Shortcut:

$PAO_2 \simeq FiO_2 \times 500$

$$PAO_2 = FiO_2(P_B - P_{H2O}) - (PaCO_2/RQ)$$

P_B is barometric pressure
P_{H2O} is pressure due to water vapour
RQ is respiratory quotient

Breathing room air at sea level:

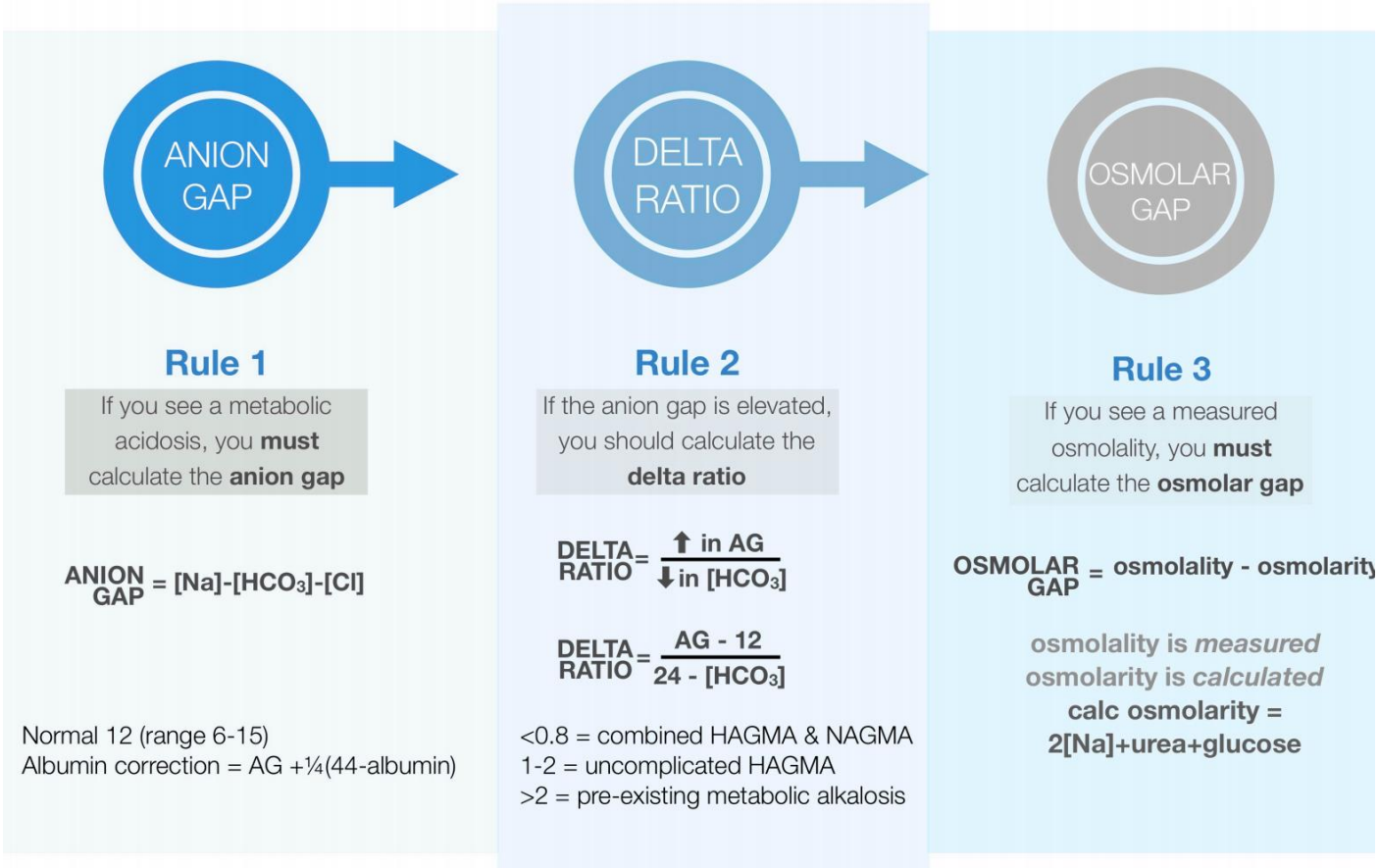
$PAO_2 = 0.21 \times (760-47) - (40/0.8)$
$= 150-100$
$= 100$ mmHg

The University of Sydney

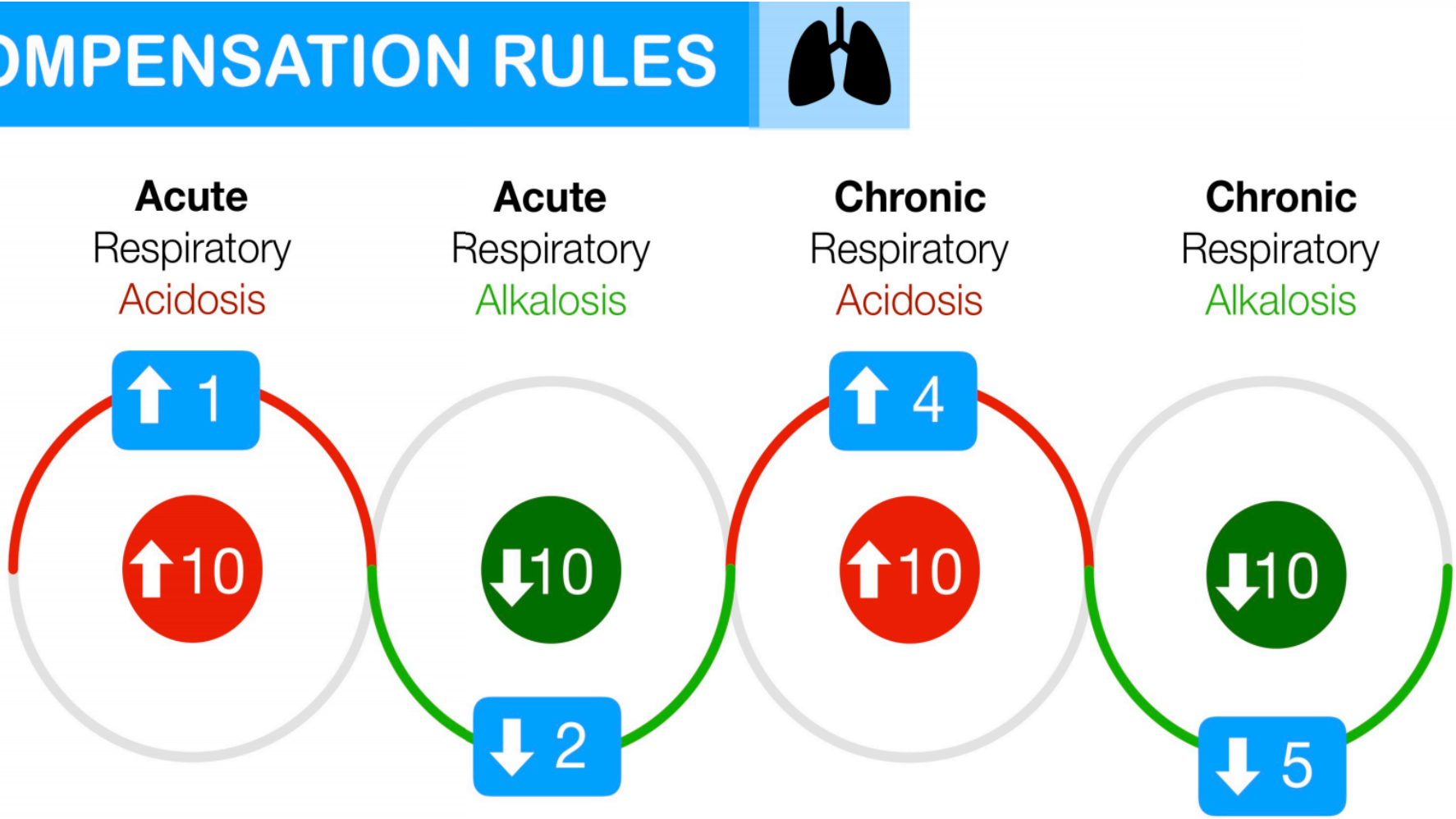
Acidosis Rules

$$\text{ANION GAP} = [Na]-[HCO_3]-[Cl]$$

Acidosis Rules



COMPENSATION RULES



HCO_3^- ⬆ 1 mmol for every 10mmHg ⬆ in CO_2>40

Acute A**C**idosis
1 *for 10*

HCO_3^- ⬇ 2 mmol for every 10mmHg ⬇ in CO_2<40

Acute A**L**kalosis
2 *for 10*

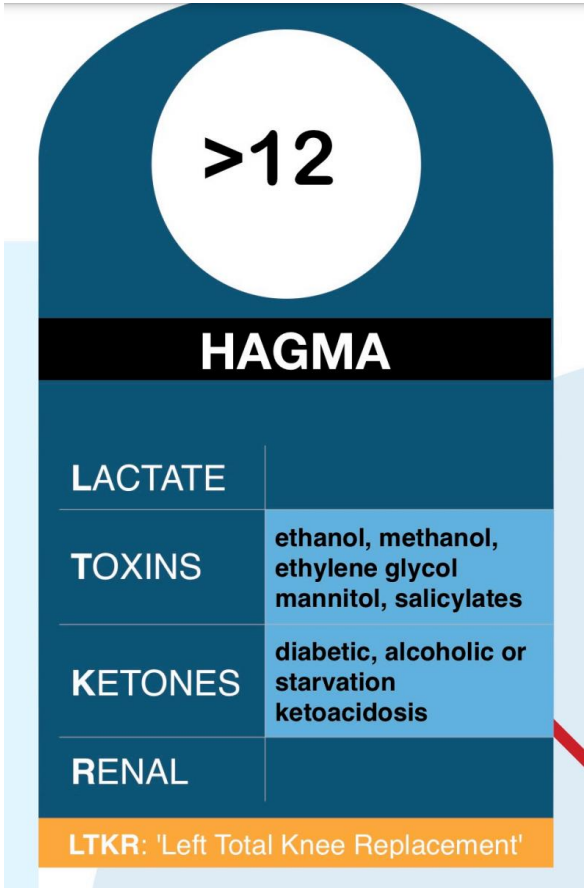
HCO_3^- ⬆ 4 mmol for every 10mmHg ⬆ in CO_2>40

Chronic A**C**idosis
4 *for 10*

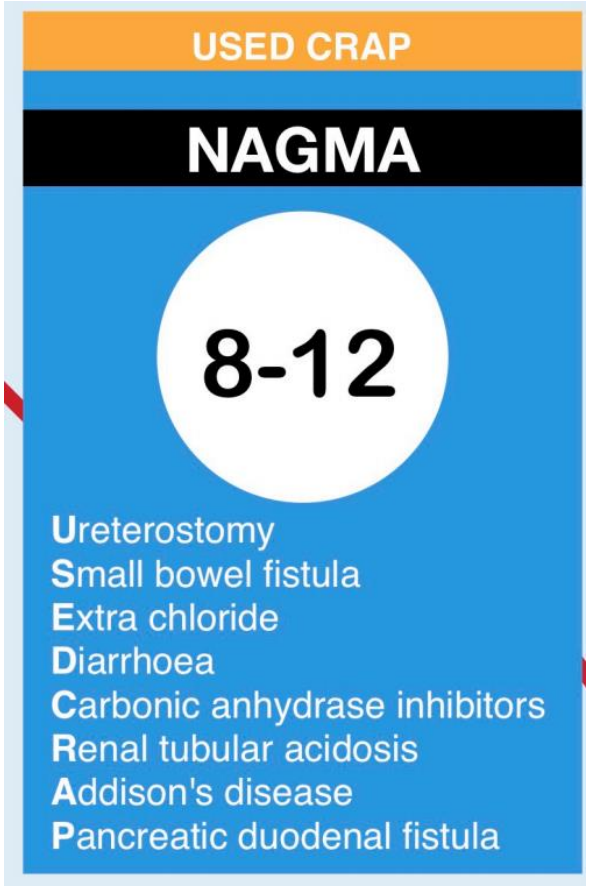
HCO_3^- ⬇ 5 mmol for every 10mmHg ⬇ in CO_2<40

Chronic A**L**kalosis
5 *for 10*

Acidosis Rules

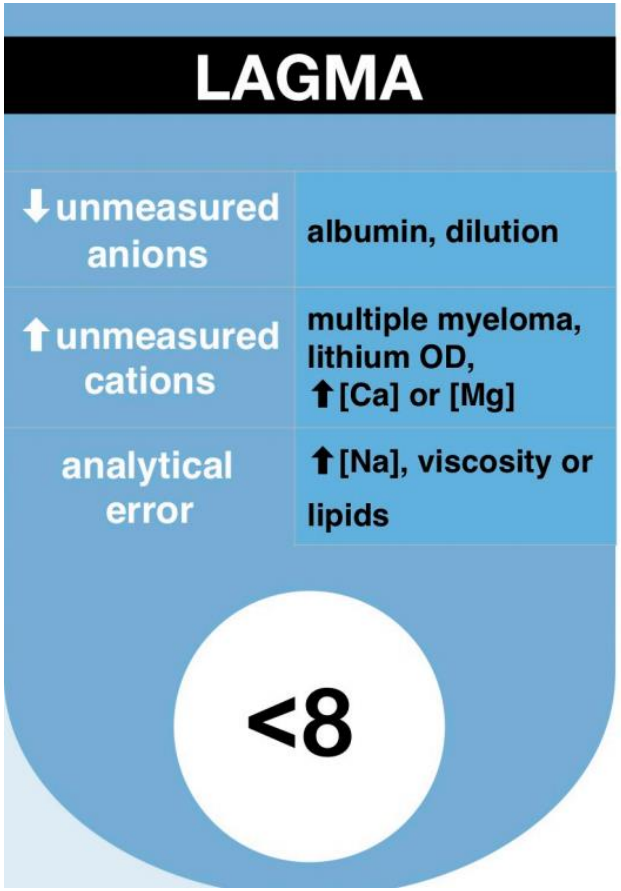


Acidosis Rules

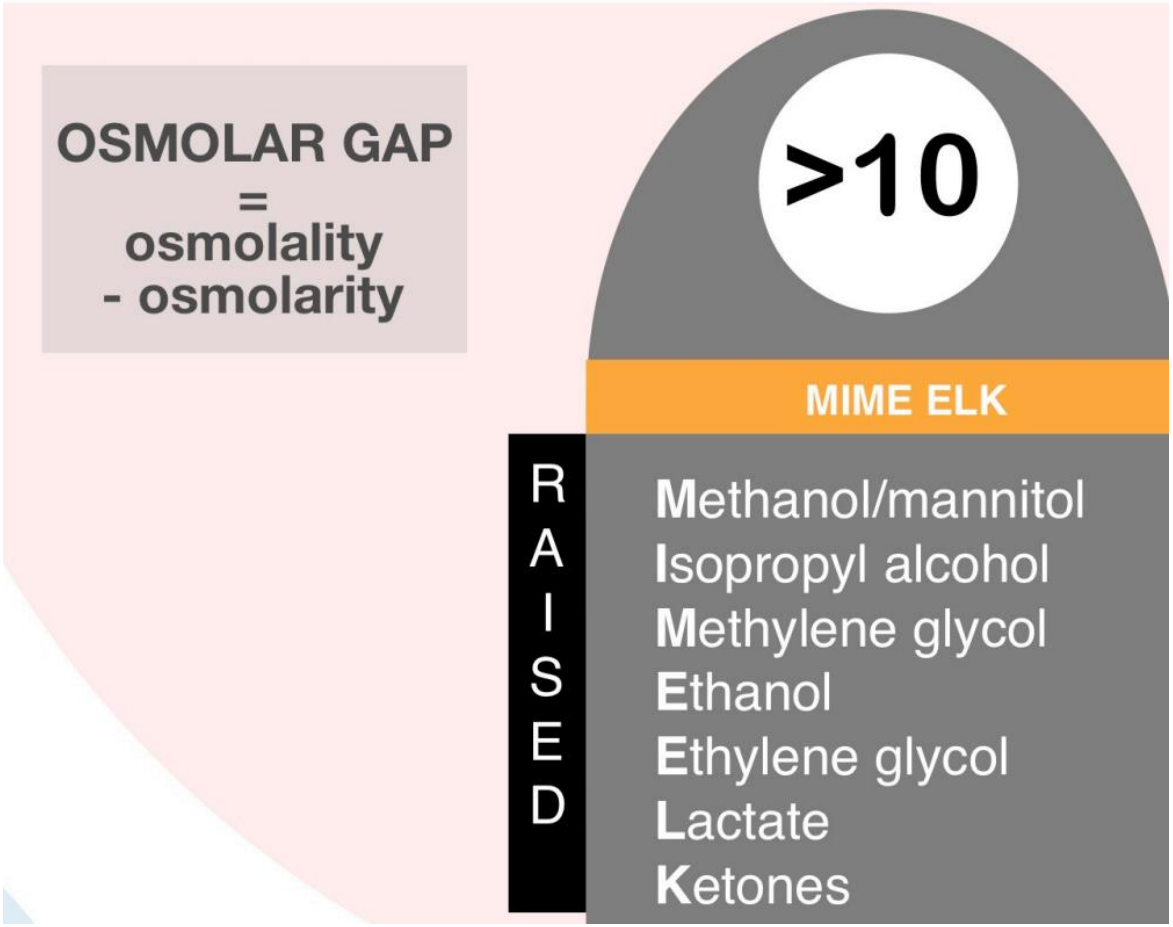


The University of Sydney

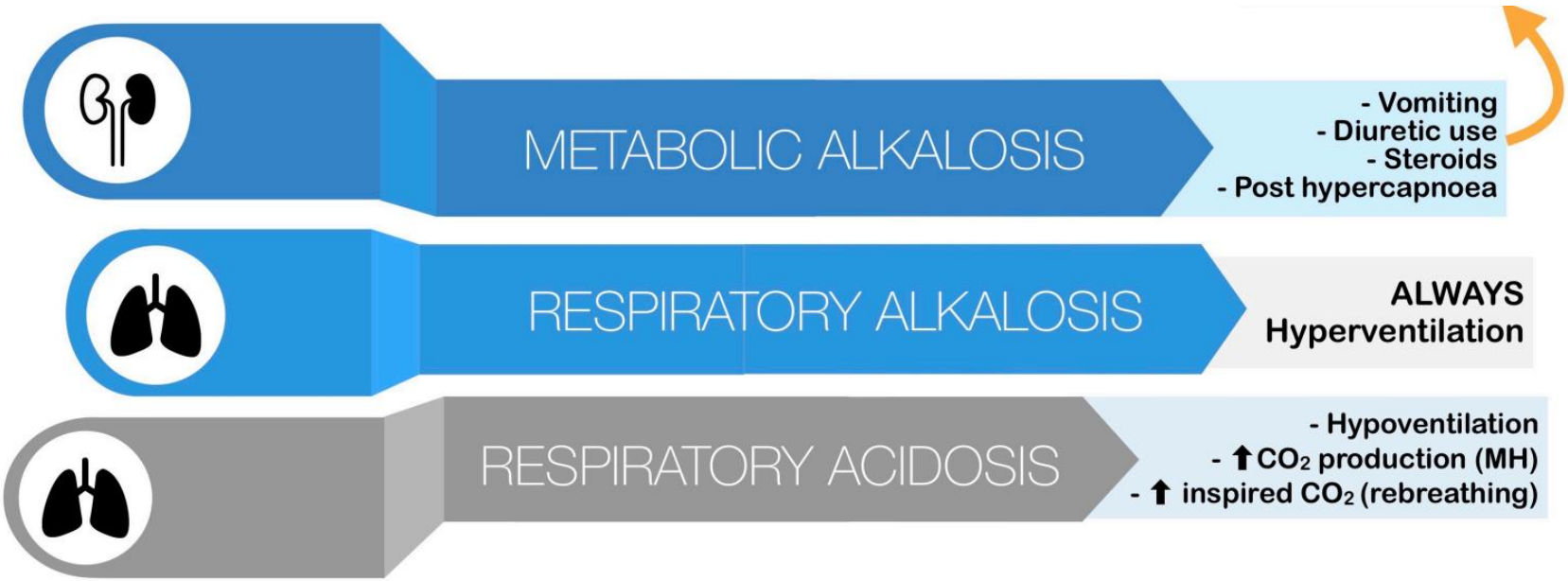
Acidosis Rules



Osmolar Gap


OSMOLAR GAP
=
osmolality
- osmolarity
>10
MIME ELK
RAISED
Methanol/mannitol
Isopropyl alcohol
Methylene glycol
Ethanol
Ethylene glycol
Lactate
Ketones

Other Problems



Blood Gas Challenge 1

Serum biochemistry and arterial blood gas

			Reference Range
FiO_2	0.50		
pH	7.05		7.35-7.45
pCO_2	66	mmHg	35-45
pO_2	247	mmHg	80-95
Bicarbonate	18	mmol/L	22-28
Base excess	-14		-3 - +3
O_2 saturation	99	%	
Na^+	131	mmol/L	
K^+	5.0	mmol/L	
Cl^-	92	mmol/L	
Urea	15	mmol/L	
Creatinine	227	micromol/L	
Glucose	50.9	mmol/L	

Rule 2

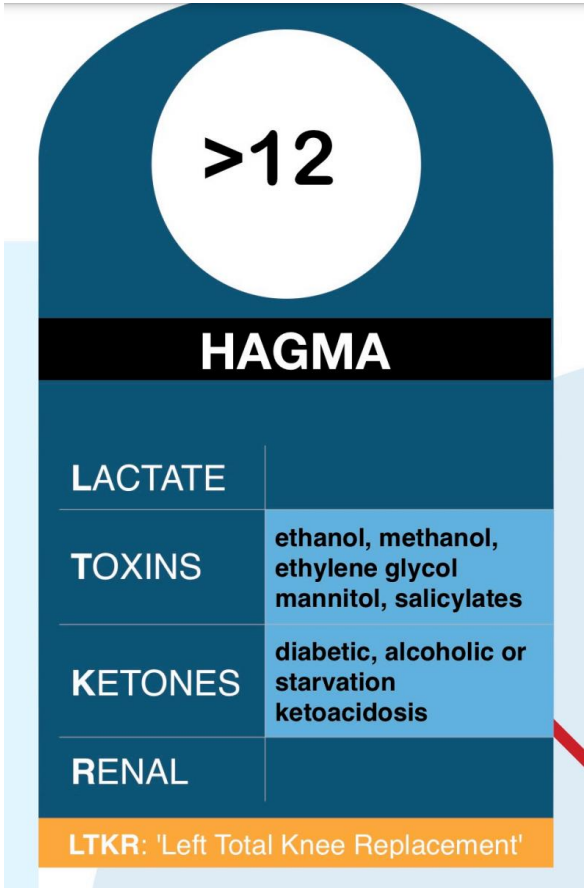
If the anion gap is elevated, you should calculate the **delta ratio**

$$\text{DELTA RATIO} = \frac{\uparrow \text{ in AG}}{\downarrow \text{ in } [HCO_3]}$$

$$\text{DELTA RATIO} = \frac{AG - 12}{24 - [HCO_3]}$$

<0.8 = combined HAGMA & NAGMA
1-2 = uncomplicated HAGMA
>2 = pre-existing metabolic alkalosis

Acidosis Rules



Blood Gas Challenge 2

FiO_2	0.21		
pH	7.24		7.35-7.45
pCO_2	92	mmHg	35-45
pO_2	45	mmHg	80-95
Bicarbonate	49	mmol/L	22-28
Base excess	10		-3 - +3
O_2 saturation	78	%	> 95
Lactate	1.2	mmol/L	< 1.3
Na^+	142	mmol/L	134-146
K^+	3.8	mmol/L	3.4-5
Cl^-	86	mmol/L	98-106
Glucose	11.4	mmol/L	3.5-5.5
Haemoglobin	184	g/L	135–180
Carboxy Hb	7	%	< 6%

The University of Sydney

Blood Gas Challenge 3

Bedside venous blood gas results included:

			Reference Range
FIO_2	0.21		
pH	7.25		7.35-7.45
pCO_2	35	mmHg	35-45
pO_2	234	mmHg	80-95
HCO_3	15.0	mmol/L	22-28
Base Excess	-11		-3 to +3
Na^+	141	mmol/L	134-146
K^+	1.1	mmol/L	3.4-5.0
Cl^-	116	mmol/L	98-106
Glucose	5.4	mmol/L	3.5-4.5

The University of Sydney

Answers

What is her main acid/base disorder?

Metabolic acidosis: low pH + normal CO_2 + normal HCO_3 + strongly negative base excess.

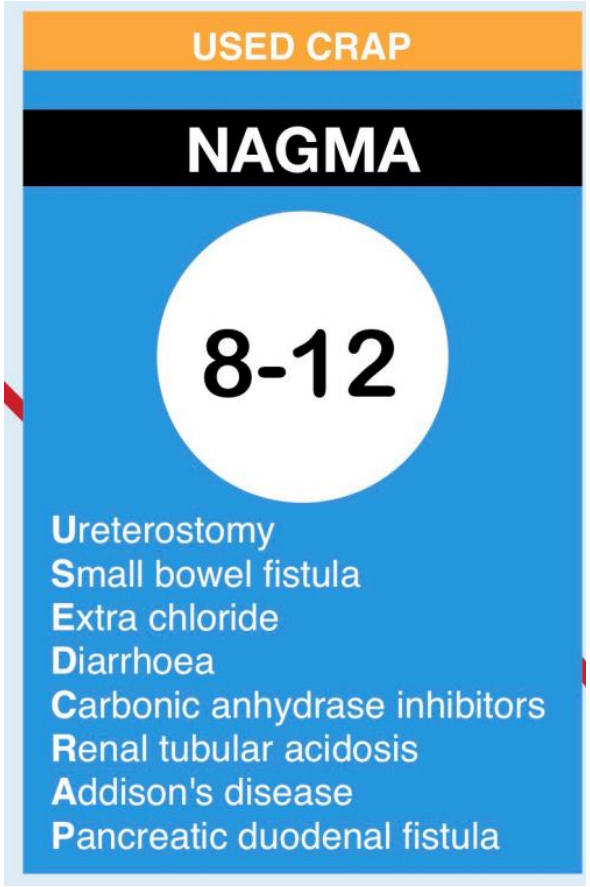
What is her anion Gap?

Na – [HCO3 – Cl]

= 141 – 15 – 116 = **10**

The University of Sydney

Acidosis Rules



The University of Sydney

Blood Gas Challenge 4

A 26 year old mechanic is brought in by ambulance after an overdose of an unknown substance. On arrival his vital signs are:

HR 106
BP 80/50
GCS 12
sats 100% on RA
RR 34

ABG

FiO2	0.21	
pH	7.15	
pO_2	115	mmHg
pCO_2	20	mmHg
HCO_3-	8	mmol/L
BE	-16	
Na	135	mmol/L
K	6.5	mmol/L
Cl	95	mmol/L
glucose	6.2	mmol/L
urea	8.1	mmol/L
lactate	5.2	mmol/L
measured osmolality	320	mosm/Kg

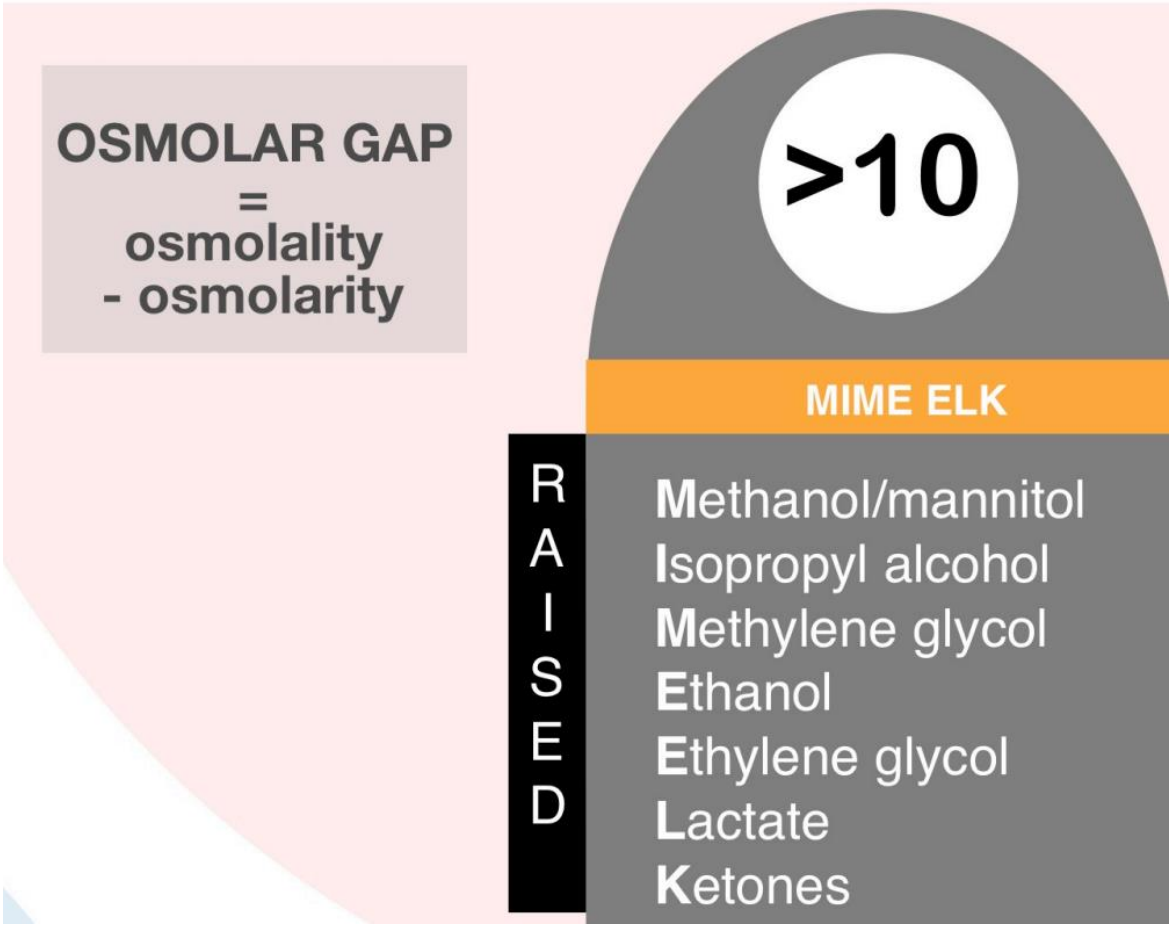
Rule 3

If you see a measured osmolality, you **must** calculate the **osmolar gap**

OSMOLAR GAP = osmolality - osmolarity

osmolality is *measured*
osmolarity is *calculated*
calc osmolarity = 2[Na]+urea+glucose

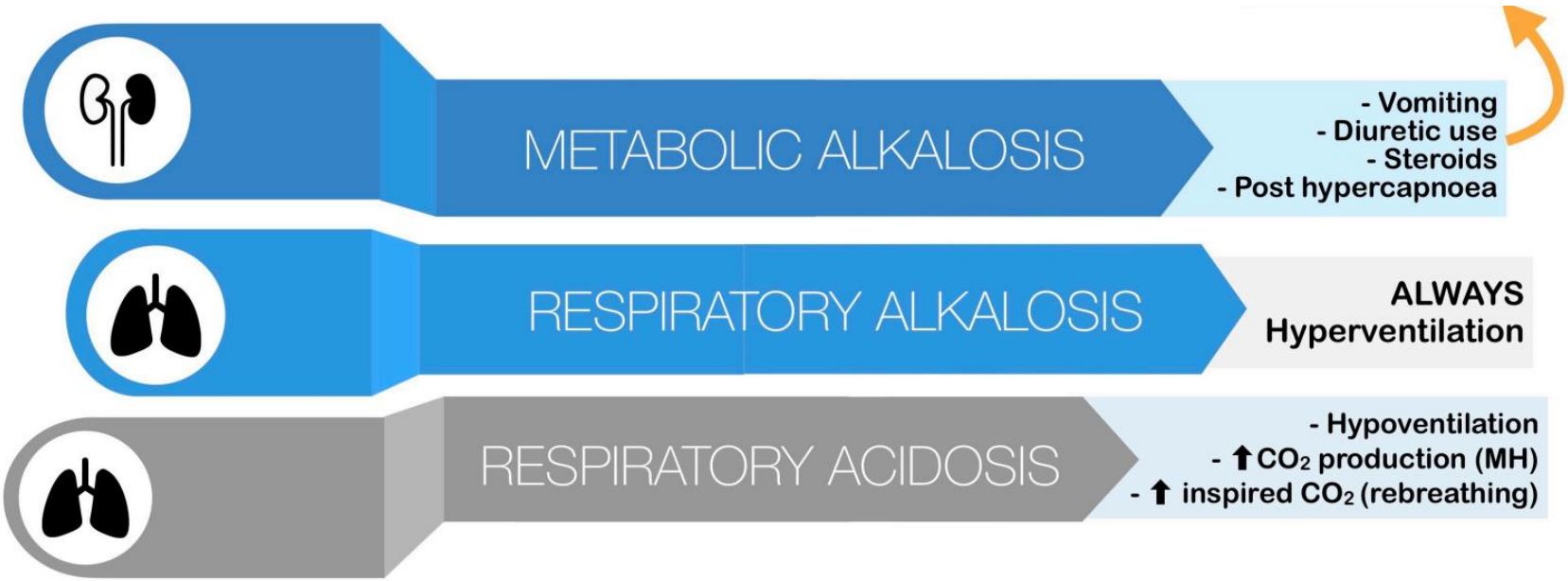
Osmolar Gap


OSMOLAR GAP
=
osmolality
- osmolarity
>10
MIME ELK
RAISED
Methanol/mannitol
Isopropyl alcohol
Methylene glycol
Ethanol
Ethylene glycol
Lactate
Ketones

Blood Gas Challenge 5

Blood Gas Values			
↑ pH	7.451		[7.350 - 7.450]
↑ pCO_2	54.5	mmHg	[35.0 - 45.0]
↓ pO_2	58.3	mmHg	[75.0 - 100]
Acid Base Status			
$cHCO_3^-(P,st)_c$	35.6	mmol/L	
$cBase(Ecf)_c$	12.7	mmol/L	
Oximetry Values			
↓ sO_2	88.5	%	[95.0 - 100.0]
↓ ctHb	99	g/L	[130 - 180]
Electrolyte Values			
↓ cK^+	2.9	mmol/L	[3.5 - 5.0]
cNa^+	144	mmol/L	[136 - 146]
↓ cCa^{2+}	1.14	mmol/L	[1.15 - 1.30]
$cCa^{2+}(7.4)_c$	1.17	mmol/L	[-]
Metabolite Values			
cGlu	5.4	mmol/L	[-]
cLac	1.5	mmol/L	[0.5 - 2.0]
Temperature Corrected Values			
pH(T)	7.451		
$pCO_2(T)$	54.5	mmHg	

Other Problems

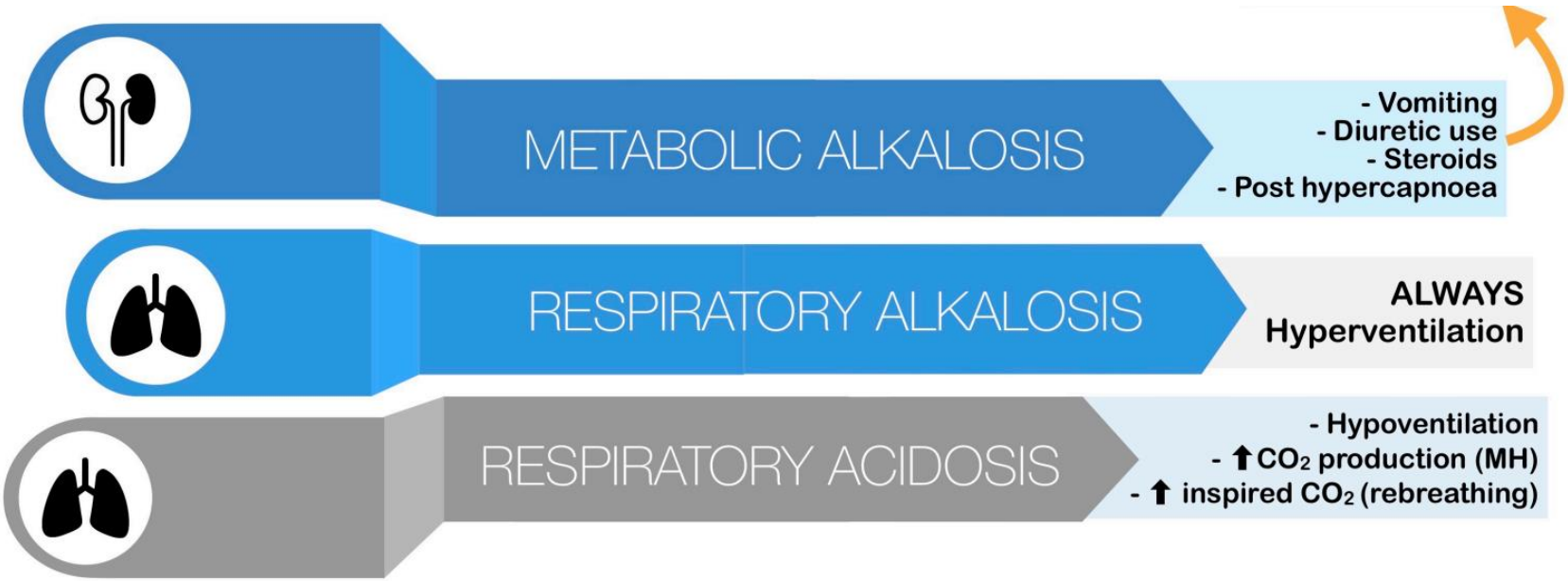


Blood Gas Challenge 6

Reference Range			
FIO_2	0.5		
pH	7.62		(7.35-7.45)
pCO_2	28.5	mmHg	(35-45)
pO_2	234	mmHg	(80-95)
Bicarbonate	30.0	mmol/L	(22-28)
Base excess	8.3		(-3 - +3)
O_2 saturation	99.8	%	(> 95)
Lactate	1.1	mmol/L	(< 1.3)
Na^+	131	mmol/L	(134-146)
K^+	2.0	mmol/L	(3.4-5)
Cl^-	90	mmol/L	(98-106)
Glucose	12.7	mmol/L	(3.5-5.5)

The University of Sydney

Other Problems




The End.