Acid Base Balance

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Normal Blood Gas Values

Values	Arterial	Venous	Capillary
pH	7.35 – 7.45	7.33 – 7.44	7.35 – 7.45
PCO_2 (kPa)	4.6 – 6.0	5.0 – 6.4	4.6 – 6.0
PO_2 (kPa)	> 10.6	5.3	Variable
HCO_3 (mmol/L)	22 – 28	22 – 28	22 – 28
BE	+1 / -2	+1 / -2	+1 / -2
Saturations	> 95	72 – 75	variable
Lactate (mmol/L)	0.5 – 2.2	0.5 – 2.2	0.5 – 2.2

Acid Base Balance

Why is acid base balance important?

- Normal metabolism results in the production of acids.

An acid is a hydrogen ion donor

A base is a hydrogen ion acceptor

- The acids produced by metabolism have to be either buffered or excreted to maintain blood pH within normal parameters

What is the main acid produced by the body as a result of normal metabolism?

Acid Base Balance

Body systems can only function with a narrow pH range

Normal pH is between 7.35 – 7.45

- as the free H^+ concentration increases, so the pH decreases, and vice versa

Systemic effects of pH < 7.35

- Right shift in oxyhaemoglobin dissociation curve
- Increased PVR
- Lower threshold for ventricular fibrillation
- Decreased response to catecholamines
- Decreased mesenteric blood flow

Systemic effects of pH > 7.45

- Decreased vascular resistance and tone
- Left shift in oxyhaemoglobin dissociation curve
- Increased response to catecholamines

Acid Base Balance

Homeostasis of free hydrogen ion concentration and therefore pH is achieved by three separate but interdependent systems

- Buffering system
- Respiratory system
- Renal system

Buffering System

- Is activated in seconds and therefore is considered first line of defence against changes in pH
- Buffer system works in pairs of weak acids and weak bases
- Whenever a buffering reaction occurs, the concentration of one member of the pair increases while the other decreases
- The most important pair of buffers are Bicarbonate and Carbonic acid

Buffering System

- CO_2 is formed by the tissues and diffuses into the capillaries where it combines with water to form carbonic acid

CO_2 and H_2O → H_2CO_3 (Carbonic acid)

- Carbonic acid dissociates to H^+ and bicarbonate

H_2CO_3 → H^+ and HCO_3^- (Bicarbonate)

- The H^+ then binds to Hb and the bicarbonate passes back into the plasma

Buffering System

In the lungs the process reverses in order to release the CO_2

- H^+ bound to the Hb recombines with bicarbonate to form carbonic acid. The Hb is then free to transport oxygen

H^+ and $HCO_3^- \rightarrow H_2CO_3$ (Carbonic acid)

- Carbonic acid then dissociates into CO_2 and H_2O

$H_2CO_3 \rightarrow CO_2$ and H_2O

- CO_2 is excreted by the lungs

Respiratory System

- Ventilation plays a major role in maintaining pH balance
- Respiratory system can activate changes in pH within minutes
- Balance is achieved through conservation or elimination of CO_2
- Impact of this system is more efficient than that of the other systems

Respiratory System

- Excessive H+ concentration (from any source) stimulates the respiratory centre in the medulla to increase respiratory rate and clear CO_2
- Conversely elevated pH due to an increase in base causes inhibition of the respiratory centre and respiratory rate falls
- CO_2 retention occurs – allows formation of more carbonic acid which buffers the excess base thus returning pH to normal

Respiratory System

The respiratory system is particularly useful at compensating for changes in pH relating to metabolic disorders

e.g. DKA through regulation of pCO_2

Sepsis through regulation of pCO_2

But if the changes in pH are related to a respiratory disorder e.g. consolidation / pneumothorax, then the respiratory system will be limited in it's ability to adjust the pCO_2 and affect the pH

Renal System

- Controls acid base balance through several active transport processes
- Compensation is a slower process
  - 1 to 2 days for respiratory alkalosis
  - 3 to 5 days for respiratory acidosis
- Renal system reacts to changes in pH by regulating the excretion / conservation of Hydrogen and Bicarbonate ions

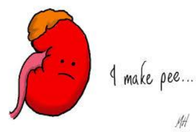
Renal System

- Low pH stimulates the excretion of Hydrogen ions into the urine
- As Hydrogen moves into the urine Sodium and Bicarbonate are reabsorbed
- Sodium Bicarbonate becomes available to buffer excessive Hydrogen ions in the circulation
- The pH increases
- The reaction is reversed when pH is > 7.45

Renal System

The renal system is particularly useful at compensating for changes in pH relating to respiratory disorders

e.g. Consolidation
Pneumothorax



Oxygen

Oxygen is pH neutral and doesn't directly affect pH

However, the effects of hypoxia do affect pH

What is your definition of hypoxia?

Disturbances in Acid Base Balance

Primary disorders of acid base balance are

- Respiratory acidosis
- Metabolic acidosis

- Respiratory alkalosis
- Metabolic alkalosis

Respiratory Acidosis

- Occurs when there is a failure to eliminate CO_2

Can you think of some causes of respiratory acidosis?

Respiratory Acidosis

- The pCO_2 rises above 6.0kPa
- The blood pH drops
- The kidneys compensate by excreting hydrogen ions and reabsorbing sodium and bicarbonate

This compensation will take days to fully activate

It will bring the pH back towards normal but the pCO_2 will remain elevated

Metabolic Acidosis

- Occurs when there is an excess of acid or a lack of bicarbonate – causing the pH to fall

Can you think of some causes of metabolic acidosis?

What effect will this have on the respiratory system in the medulla?

Metabolic Acidosis

- There is a high lactate or ketone level or the bicarb is below 22mmol/L
- The blood pH increases
- The medulla enforces increased rate and depth of respiration

This compensation will take a few minutes to fully activate

It will bring the pH back towards normal but the lactate / ketones / bicarb will remain abnormal

Metabolic Alkalosis

Ill-health will mostly result in an acidosis, but very occasionally children may present alkalotic

Metabolic Alkalosis

- Occurs when there is a loss of acid causing the pH to increase

Can you think of some causes of metabolic alkalosis?

What effect will this have on the respiratory system in the medulla?

Respiratory Alkalosis

- Occurs when the pCO_2 falls below 4.6kPa

Can you think of some causes of respiratory alkalosis?

What effect will this have on the renal system?

Arterial Blood Gas Analysis

Systematic approach to blood gas analysis:

- How is the child? What is the history?
  - this will provide valuable clues to help with the interpretation of the gas
- Assess oxygenation
- Determine the pH
  - is the child acidotic or alkalotic?
- Determine the respiratory component
  - pCO_2 above 6.0 kPa – respiratory acidosis or respiratory compensation for a metabolic acidosis
  - pCO_2 below 4.6 kPa – respiratory alkalosis or respiratory compensation for a metabolic acidosis
- What is the bicarbonate?
  - < 22 mmol/L – metabolic acidosis or renal compensation for a respiratory alkalosis
  - > 26 mmol/L – metaboilc alkalosis or renal compensation for a respiratory acidosis
- What is the base excess?
- What is the lactate?
- How does this gas compare to the last one?

Scenario A

Lucy, age 5yrs, is admitted to ED with acute asthma
O/A wheezy, resp's 50, H.R. 140
ABG in 100% O_2 shows:-

pH	7.2
pCO_2	8.7 kPa
pO_2	9.3 kPa
HCO_3	25 mmol/L
BE	+1
Lactate	0.9 mmol/L

How would you interpret this blood gas?

Scenario B

John, aged 9 mths, was premature and has chronic lung disease.
He presents with an acute viral chest infection and is admitted for Vapotherm / Optiflow support
His ABG in air shows:-

pH	7.33
pCO_2	9.6 kPa
pO_2	6.9 kPa
HCO_3	39 mmol/L
BE	+15
Lactate	0.7 mmol/L

How would you interpret this blood gas?

Scenario C

Charlie, aged 6 mths, is admitted with 10% dehydration. He is pale and lethargic with a respiratory rate of 48

ABG in room air shows:-

pH	7.24
pCO_2	3.8 kPa
pO_2	11.7 kPa
HCO3	17 mmol/L
BE	- 22
Lactate	5 mmol/L

How would you interpret this blood gas?