Subject : Acid-Base Balance&Arterial Blood Gases

Lecture :

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الفريق العلمي - النادي الطبي

CLINICAL SKILLS

Acid- Base Balance + Arterial Blood Gases

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Learning Objectives for ABGs

- Understand the physiology behind acid-base regulation in the body at both the respiratory system and the metabolic system particular the kidney
- Use of ABGs for assessment and monitoring
- Being able to interpret Arterial Blood Gas results
- Understanding how to measure the anion gap and its importance
- Practice examples

Physiological background of acid-base balance

- You eat 70-100mmol of acid a day in your normal diet! usually in the form of sulfuric
- Your pH in your blood is tightly controlled between 7.38-7.42 and relies on the H^+ ions in the extracellular and intracellular fluid
- Acidosis is a pH below 7.38 (an increase in H^+ ions) (يعني لو مثلاً Acidosis دا 7.35)
- Alkalosis is a pH above 7.42 (a decrease in H^+ ions)
- There are buffers in the body to maintain a tight blood pH such as haemoglobin (intracellular), calcium carbonate and phosphate (in your bone tissue) and hydration to carbon dioxide (bicarbonate-carbonic acid buffer pair)

🔻إنما النصر صبر ساعة

CO_2 is an acidic gas

⇌ → can go both ways

Henderson-Hasselbalch equation

$$H^+ + HCO_3^- \rightleftharpoons H_2CO_3 \overset{\text{carbonic anhydrase}}{\rightleftharpoons} CO_2 + H_2O$$

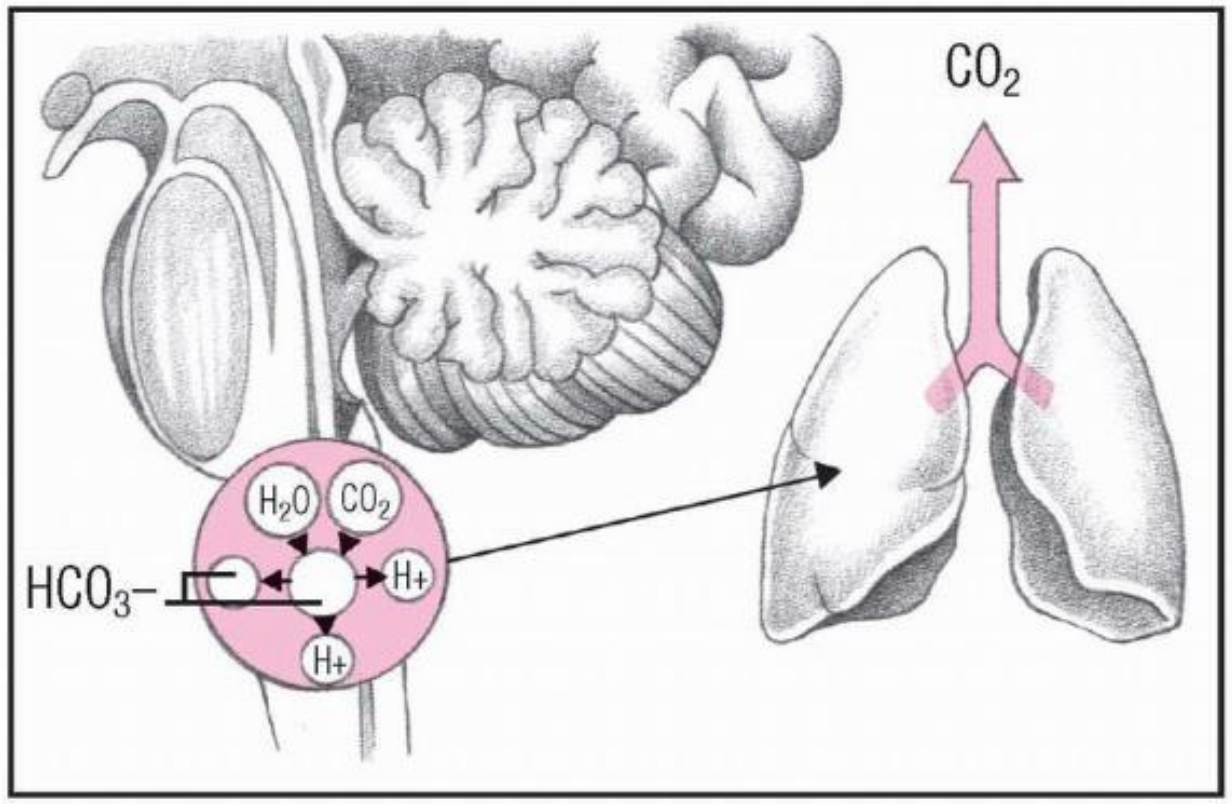
- An increase in H^+ ions (decreasing pH) drives the reaction to the right and so there is a drop in plasma HCO_3^- and an increase in the arterial pressure of CO_2 ($PaCO_2$ - measured in kilopascals (1)) or mm of mercury (2)
- Acidosis (a drop in pH due to increase of H^+ ions OR drop in HCO_3^- ions) stimulates increased ventilation which blows off excess CO_2 generated

cut

- باختصار : زيادة الـ (H^+) سيؤدي إلى نقصان الـ (PH) ونقصان الـ (HCO_3^-) وبالتالي زيادة الـ (CO_2)، طيب شو بعمل الجسم

كرد فعل ؟ بزيد الـ (Ventilation) عشان يدخل O_2 ويطلع CO_2 وبالتالي ما بضل الـ (CO_2) يتراكم بالجسم ووقتها رح يرد يرتفع الـ (PH)

Exhalation of acidic CO_2 gas through the respiratory system



1) If respiratory rate increases what happens to the blood pH? it goes up ↑

لأ نه قاعدين بنطلع حمض عن طريق الزفير

2a) If breathing is ineffective (slow or shallow) what happens to the blood CO_2? goes up ↑

لأ نه مش قادرين نطلعه بالزفير

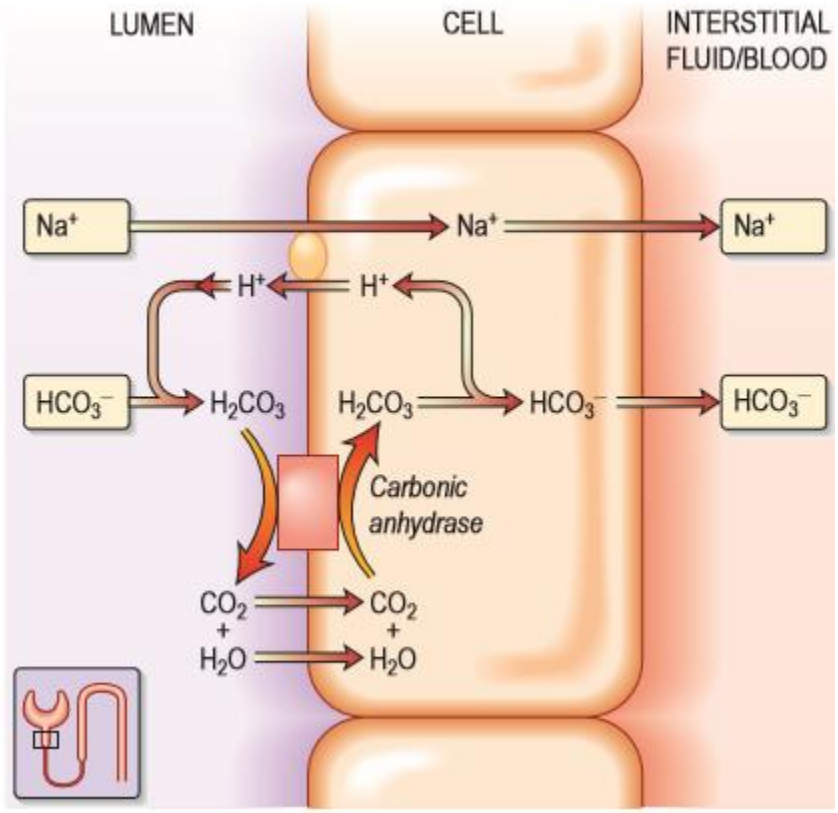
b) Thus what happens to the blood pH? goes down ↓ because you got an acidic gas in the blood system and so the pH drops

Plasma HCO_3^- needs to be maintained at 25 mmol/L and increased ventilation doesn't replace the HCO_3^- ions used in the buffering process so….

بدنا مصدر يجود لنا الـ (HCO_3^-) عشانه نستعمله

So…. which other organ is involved in regulating acid-base balance excreting excess H+ ions and reabsorbing HCO_3^- ions? Kidney

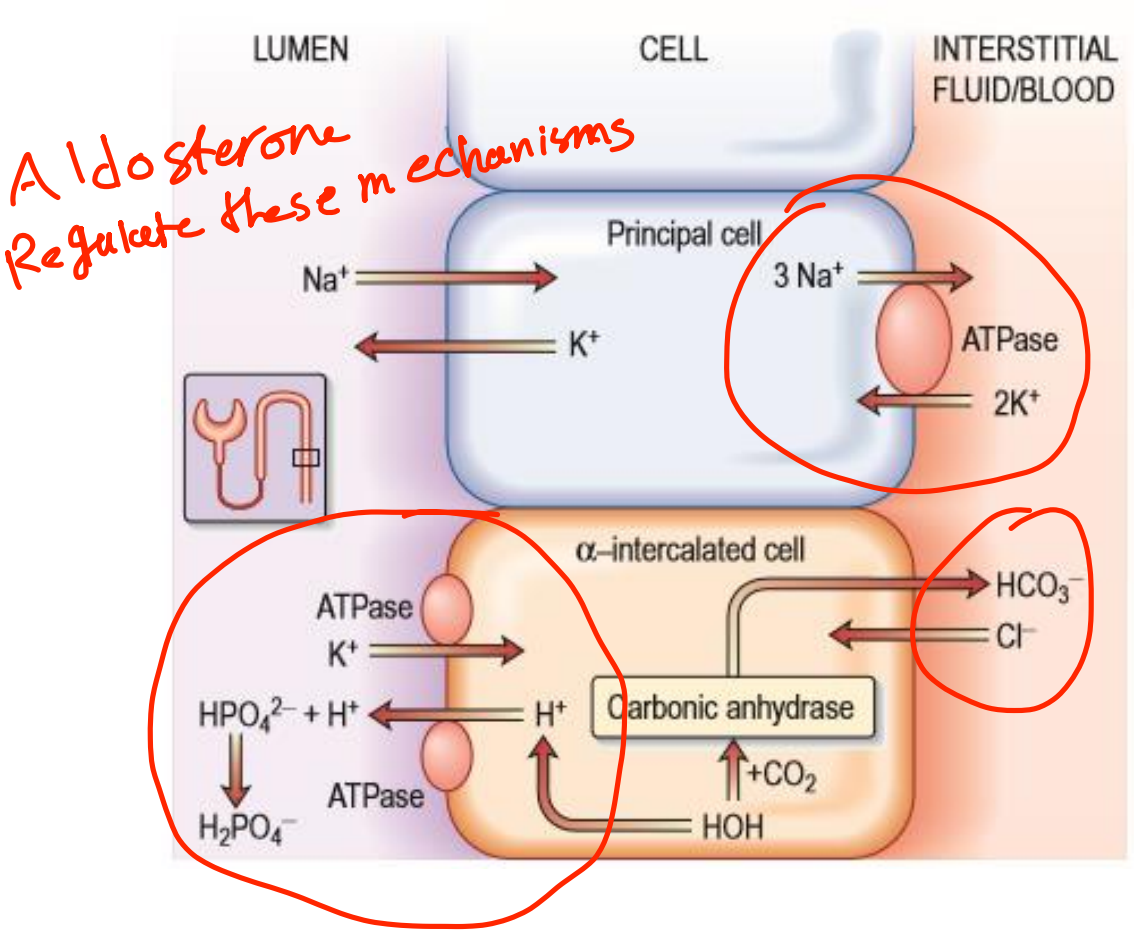
Reabsorption of Sodium Bicarbonate in the kidney



- Exchange of sodium (Na^+) with hydrogen (H^+) on luminal wall in proximal tubule
- Hydrogen (H^+) and bicarbonate (HCO_3^-) form H_2CO_3 in the lumen
- Carbonic Acid (H_2CO_3) is broken down again by the carbonic anhydrase enzyme in the luminal wall into water (H_20) and carbon dioxide (CO_2) which is absorbed intracellularly
- Once again the carbonic anhydrase enzyme in the luminal wall drives the reverse reaction to H_2CO_3 which breaks down to hydrogen (H^+) which is excreted and bicarbonate (HCO_3^-)which is reabsorbed into the blood which is also exchanged with sodium so you get sodium bicarbonate that goes back into the the blood circulation.

اللهم ارزق أهلنا في فلسطين الفرج والنصر القريب🤲

Excretion of Hydrogen in the kidney



- Hydrogen (H^+) ions from cortical collecting ducts is indirectly linked to the absorption of sodium (Na^+)
- Aldosterone enters `Principal cells' in collecting duct and opens the Na^+ channel (increases activity of the Na^+/K^+ ATPase enzyme)
- Aldosterone also directly stimulates H^+ ATPase enzyme in the alpha-intercalated cell that enhances H^+ excretion

In Summary

- Carbonic acid (H_2CO_3) links the respiratory and metabolic systems
- Advantage of this is that the components can vary independently of each other e.g. if respiratory system falters the metabolic system can compensate and vice versa
- Respiratory system controls carbon dioxide (CO_2) in the blood (which is an acidic gas)
- The kidneys (metabolic system) control level of sodium bicarbonate ($Na^+HCO_3^-$) in the blood (which is a base and buffer of hydrogen ions)
- Kidneys can further regulate the pH be excretion of hydrogen (H^+)ions

When to take an arterial blood gas?

Patients who are in:

1. Respiratory failure
2. Critically ill or likely to deteriorate quickly
3. Sepsis
4. Multiorgan failure
5. Uncontrolled diabetes
6. Taken an overdose or toxin

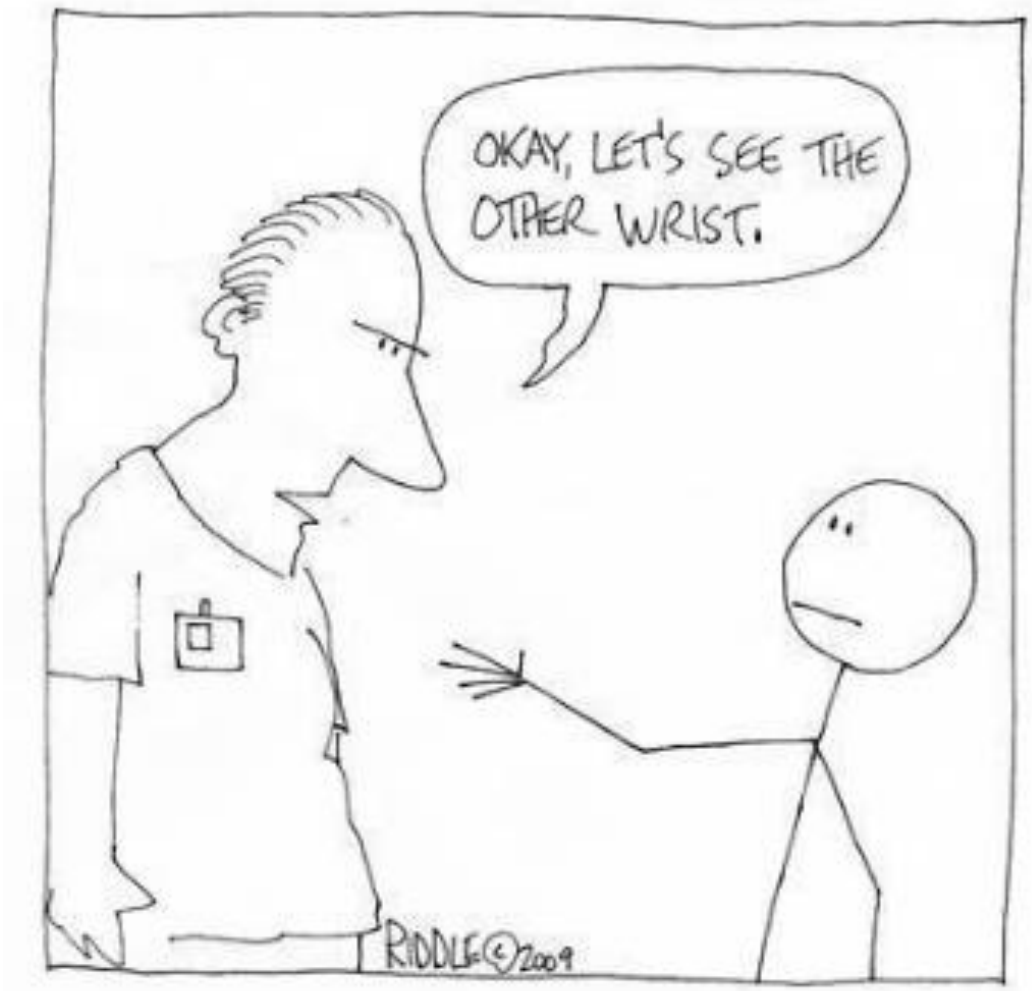
شرحهم
بالتالية اللي تحت

DON’T TAKE AN ABG UNLESS IT WILL CHANGE YOUR MANAGEMENT

When to take an arterial blood gas?

patients who arrive in the emergency department who are hypoxic maybe they have low saturations and respiratory failure this is good opportunity to take an arterial blood gas someone who critically ill or likely to deteriorate you want to know how they are if they're septic confused you want to know the level of their PH and what you need to do to correct this if someone is in multiple organ failure perhaps on ICU you may be able to offer bases to help regulate the pH or maybe change the ventilator to different respiratory to help blow off more carbon dioxide depending what's going on if somebody comes in and has a diabetic keto acidosis with uncontrolled diabetes you want to know if there's a metabolic acidosis and if there's anion Gap and how they are if someone's taking an overdose or toxin that potentially could cause a metabolic acidosis or alkalosis or orally acidosis this is again the need to take an ABG but remember don't just take an ABG unless it will change your management taking an ABG is painful it's difficult and it's not something to take lightly.

it is just a joke



THIS WAS GOING TO BE A TOUGH ABG.

Normal Arterial Blood Gases

pH	7.35-7.45	
$PaCO_2$	4.7-6.0 kPa	(35-45 mmHg)
PaO_2	11-13.5 kPa	(83-102 mmHg)
HCO_3^-	22-28 mmol/L	
Anion gap	10-16 mmol/L	

ماحكاهم

🔻 اللهم غزة بسماءها وجبالها أرضها وهوائها كبارها وصغارها

Scenario 1 – A breathless man

A 60 year old man with a history of chronic obstructive pulmonary disease presents to the emergency department with increasing shortness of breath, fever, and a productive cough of yellow-green sputum. He is unable to speak in full sentences. His wife says he has been unwell for two days.

this man looks like he has respiratory failure. he's struggling to breathe is unable to finish his sentences and it looks like he's got an exacerbation of a COPD with the symptoms he describes.

Measurement of arterial blood gas shows:

pH 7.2 (Acidosis) (Normal range 7.35-7.45)

O_2 7.9 kPa (59 mmHg) (Normal range 11-13.5kPa/ 83-102mmHg)

$PaCO_2$ 9.3 kPa (70 mmHg) (Normal range 4.7-6.0kPa / 35–45mmHg)

HCO_3^- 27 mmol/L (Normal range 22-28 mmol/L)

much higher than the normal range. it is retaining CO_2

How would you interpret this ABG?

so this fits with the acidosis as a respiratory cause because we know that carbon dioxide is an acidic gas so this is respiratory acidosis what about the bicarbonate? well it's within the normal range so we're not seeing any compensation there's no change in the metabolic system at the moment he is hypoxic his oxygen levels are less than normal but this doesn't affect the acid base balance.

Stepwise approach to looking at Arterial blood gas results

Methodology to interpret ABG results

Step 1: Is there an acid-base abnormality—that is, is the pH outside the normal range? if it's higher than the normal range we know it's got an alkalosis if it's lower than the normal range then we know the patient has an acidosis.

Step 2: Is the respiratory ($PaCO_2$) or the metabolic (HCO_3^-) component abnormal, and is it the primary cause of the acid-base abnormality—that is, does it tell the same story as the pH?

if it's an acidosis is it a respiratory component when we look at the CO_2 level the arterial pressure of the CO_2 is it high or is it a

Step 2a: If there is metabolic acidosis—that is, a low pH and a low HCO_3^-, it may be useful to take an additional step and calculate the anion gap.

this can be useful to tell us potential cause for the metabolic acidosis and how well the patient is

Step 3: Is there compensation? → we are going to look at the opposite system

if there's a respiratory acidosis as the bicarbonate level also gone up to try and buffer the CO_2 is the compensation

Step 4: What does the PaO_2 tell you? is it type one or type two respiratory failure now the arterial pressure of oxygen as we said earlier does not affect the acid base balance it just tells you why the patient's hypoxic and if they got respiratory type one or two failure.

Step 4 - What does the PaO_2 tell you?

- Remember PaO_2 does NOT affect acid-base balance
- If a patient has hypoxaemia if PaO_2 less than 85mmHg on room air (although not clinically important unless below 65mmHg) classified as respiratory failure
- Type I respiratory failure is when patient has hypoxaemia in absence of hypercapnia (no raised $PaCO_2$)
- Type II respiratory failure is when patient has hypoxaemia in presence of hypercapnia (raised $PaCO_2$) – this indicates *hypoventilation*

Anion gap and its use in Metabolic Acidosis

$$\text{Anion gap} = (Na^+ + K^+) - (Cl^- + HCO_3^-) = 10\text{-}16 \text{ mmol/L}$$

- The number of anions and cations should be equal, but a standard blood analysis does not measure them all, resulting in a difference of 10-16 mmol/L. Some causes of metabolic acidosis result in an increased anion gap and others result in a normal anion gap.

There is *no increase in anion gap* when there is a *loss of bicarbonate*. It is usually associated with a concomitant rise in plasma chloride including:

- Renal tubular acidosis
- Severe diarrhoea (intestinal secretions below the stomach contain a large amount of bicarbonate)

$(Na^+ + K^+) - (\uparrow Cl^- + \downarrow HCO_3^-)$ ويعوضه (آ Cl) راح ينزل الـ (A.G) رأيته رح ينزل الـ (HCO_3^-) مش راح ينزل الـ (A.G) ويعوضه (آ Cl) لو زاد الـ (HCO_3^-) مش راح ينزل الـ (A.G) رأيته رح ينزل الـ (آ Cl) ويعوضه

Causes of Metabolic Acidosis and an *Increased* Anion Gap

An increase in anion gap (over 16 mmol/L) occurs when there is increased production of organic acids, such as ketones and lactic acid, or reduced excretion of them including:

- Lactic acidosis—shock, infection, tissue ischaemia
- Ketoacidosis—diabetes mellitus, alcohol abuse
  - ↳When it is out of control
- Urate—renal failure
- Poisoning— aspirin, metformin, methanol

Scenario 2

A six year old boy is taken to the ER department with vomiting and a decreased level of consciousness. His breathing is slow and deep (Kussmaul breathing), and he is lethargic and irritable in response to stimulation. He appears to be dehydrated—his eyes are sunken and mucous membranes are dry—and he has a two week history of polydipsia, polyuria, and weight loss.

polydipsia of drinking lots of fluid often affinity for sugary drinks

he's got polyuria going to the toilet a lot and he's got weight loss.

Scenario 2 – ABG result

الشرح في الصفحة التالية

Measurement of arterial blood gas (ABG) shows:

pH 7.2 (Acidosis	(Normal range 7.35-7.45)
PaO_2 13.3 kPa (100 mm Hg)	(Normal range 11-13.5 kPa)
$PaCO_2$ 3.3 kPa (25 mm Hg)	(Normal range 4.7-6.0 kPa)
HCO_3^- 10 mmol/L	(Normal range 22-28 mmol/L)

Other results are Na^+ 126 mmol/L, K^+ 5 mmol/L, and Cl^- 95 mmol/L.

1) What is your assessment of the ABG?

2) What is the anion gap?

Anion gap = $(Na^+ + K^+) - (Cl^- + HCO_3^-)$ = 10-16mmol/L (normal range)

Anion gap = (126 +5) - (95+10) = 26

here is the result of this young boy notice the pH is 7. 2 which shows an acidosis , this is due to the respiratory system well no it's not because the CO_2 is low that doesn't make sense for air acidosis it's a metabolic acidosis because the bicarbonate has dropped so what's happen is that the respiratory system is compensating for this metabolic acidosis remember from the scenario that the young boy had kussamaul breathing so it was deep and slow hypoventilating trying to reduce the amount of carbon dioxide blown off.

- the normal range for anion gap is 10 to 16 this is a high anion gap because the cause of this metabolic acidosis is a new diagnosis of diabetes with keto acidosis.

اللهم صلِّ وسلم وبارك على محمد وعلى آله وأصحابه أجمعين

Scenario 3

Tachycardia: fast heart rate

Tachypnoeia: fast respiratory rate

A 12 year old girl attends the emergency department after falling and hurting her arm. In triage she is noted to be tachycardic and tachypnoeic. She is given some pain killers. While waiting to be seen by the doctor, she becomes increasingly hysterical, complaining that she is still in pain and now experiencing muscle cramps, tingling, and paraesthesia.

تنميل

Scenario 3 – ABG result

Measurement of arterial blood gas shows

pH 7.5	(Normal range 7.35-7.45)
PaO_2 15.3 kPa (115 mm Hg)	(Normal range 11.0-13.5 kPa)
$PaCO_2$ 3.9 kPa (29 mm Hg)	(Normal range 4.7-6.0 kPa)
HCO_3^- 24 mmol/L	(Normal range 22-28 mmol/L)

What does this result show? this is the result of the ABG noce the pH is high um so she's got an alkalosis is it a metabolic alkalosis well know it's not because the bicarbon it's normal but notice the CO_2 level is less than the normal range and this is to cost this girl is become hysterical she's got pain she's tnic she's hyperventilating she's blowing off the excess carbon dioxide

الشرح بالسلايد التالي

Summary of pH, $PaCO_2$ and Bicarbonate

( ) Compensation

Primary condition	pH	$PaCO_2$	Bicarbonate
Respiratory acidosis	↓	↑	(↑)
Respiratory alkalosis	↑	↓	(↓)
Metabolic acidosis	↓	(↓)	↓
Metabolic alkalosis	↑	(↑)	↑

in summary:

1) Respiratory acidosis is a low PH with a high arterial pressure of carbon dioxide you may or you may not get a compensation that's why it's in Brackets of bicarbonate which would go up.

2) Respir alkalosis gives you a higher pH a lower arterial pressure of carbon dioxide and you may get compensation or you may not from the bicarbonate levels in the Met metabolic system.

3) Metabolic acidosis is a low PH secondary to a low bicarbonate respiratory system May compensate and you get a reduction in the CO_2.

4)Metabolic alkalosis is a high pH with a high bicarbonate level and you may get compensation in the respiratory system with an increase in the arterial pressure of CO_2.

How do we use ABGs for assessment and monitoring?

- Monitoring oxygen for COPD patients – concern regarding CO_2 retention if giving oxygen and changing rate of oxygen flow
- Assessment for Long Term Oxygen Therapy (LTOT) of COPD patients – do they meet the criteria for LTOT?
- Assessment of how ill someone is and monitoring required – e.g. DKA and need to go on ICU or step down to HDU bed…
- Correction of acid-base of patient on ICU e.g. use of bicarbonate or increasing the respiratory rate on the ventilator

- for monitoring oxygen for COPD patients particular if you're concerned regarding carbon dioxide retention particular if you're giving high flow oxygen as this may cause hypocapnea and they may retain carbon dioxide particularly as you reduce that hypoxic drive and and they drop off with their breathing and suddenly they don't have the drive to breathe anymore because they've being hypoxic they have chronic hypoxia and this hypoxia has caused them to have a spiritual Drive with the CO_2 levels if you suddenly give lots of oxygen they don't have that hypoxic drive anymore and therefore they retain carbon dioxide so often you have a a blood gas taken at the beginning of someone in the time of the emergency department and then you may repeat the ABG after 2 hours of oxygen high level oxygen to see whether the one of those patients that retains carbon dioxide if you give them high flow oxygen.

- another reason not to give patients long-term oxygen therapy talked about testing someone how ill someone is particularly in the monitoring required someone who's had a DKA do they need to go on ICU an is okay maybe they're okay in HDU setting and if someone's been on an ICU bed if the arterial blood gases are improving you may want to consider stepping down the patient to HDU again we talked about the use of ABG on ICU to help correct acid base balance you might use it bicarbonate or you might do something with a ventilator to reduce or increase the respirator rate depending what the pH is .

Practice Examples of ABGs

1a. What does the following ABG show? Metabolic Alkalosis

pH	7.48	(7.35-7.45)
pCO_2	2.9 kPa	(4.9-6.1)
pO_2	15.5 kPa	(10-13.1)
HCO_3	17	(22-28)

1b. Do you know any causes of this?

Causes of Metabolic Alkalosis

- Loss of gastric secretions - vomiting, nasogastric suction.
- Loss of colonic secretions – chloride losing diarrhoea, villous adenoma.
- Thiazides and loop diuretics (after discontinuation) → After you stop them, can cause a metabolic alkalosis
- Posthypercapnia if someone is retained CO_2 and after this moment, he can develop a metabolic alkalosis
- Cystic fibrosis
- Urinary loss of chloride – high blood pressure, adrenal adenoma, renovascular disease, glucocorticoid remediable aldosteronism, renin secreting tumour, Cushing's syndrome, liquorice ingestion….

2a What does this ABG show? Respiratory acidosis

pH	7.20	(7.35-7.45)
pCO_2	92mmHg	(35-45mmHg)
pO_2	76mmHg	(75-100mmHg)
HCO3	21	(22-28)

2b Do you know any causes of this condition?

Causes of Respiratory Acidosis

- Hypoventilation
- COPD
- Airway obstruction
- Chest trauma
- Drug overdose
- Pulmonary oedema
- Neuromuscular disease

Clinical Scenario

72 year old Yusuf Abu Raif is a lifelong smoker and takes a Ventolin and Spiriva (Tiotropium) inhaler. Over the last 3 days he has become increasingly breathless and has a productive cough. On arrival in the ER department he is found to have an oxygen saturation of 75% and is put on 100% oxygen at 12L/min. His initial ABG is below and then it is repeated after 2 hours after he becomes increasingly confused.

	Initial ABG on air		After 2 hours on 100% oxygen	
pH	7.44		pH	7.20
paO_2	52mmHg	(75-100mmHg)	paO_2	70mmHg
$paCO_2$	63mmHg	(35-45mmHg)	$paCO_2$	80mmHg
HCO3	42	(22-28)	HCO3	48

hypoxic before giving oxygen (chronic hypoxia)

What do these results show has happened?

شرحه تحت

notice when he first comes in before he has the oxygen is hypoxic so therefore you put him on the oxygen he's got normal pH but already he's retaining CO_2 so he's got a chronic hypoxia and is it retains CO_2 you know at this moment it's got already some compensation from the metabolic system maintaining his pH after two two hours look what's happened to the pH it's dropped it's become acidotic yes sure his hypox improved but correspondingly his CO_2 levels gone up it's become more hypercapneic causing his confusion and so there's also been a compensation from the metabolic system increased level of bicarbonate but this has shown that he's retaining CO_2 and oxygen and we need to reduce his oxygen levels and put him on a less flow oxygen or maybe stop it for a while until it hopefully comes round again.

Metabolic Acidosis	**Metabolic Alkalosis**
Diabetic Ketoacidosis Diarrhoea Renal failure Shock Aspirin overdose Sepsis	Loss of gastric secretions Overuse of antacids K+ wasting diuretics
Respiratory Acidosis	**Respiratory Alkalosis**
Hypoventilation COPD Airway obstruction Drug overdose Chest trauma Pulmonary oedema Neuromuscular disease	Hyperventilation Hypoxia Anxiety High altitude Pregnancy Fever

just summary

لا تنسو الرعاء لأهلنا في غزه بقلب
مؤمن بالله والفرج من الله
لعل دعوة تستجاب من مؤمن