PARTNERSHIP IN CRITICAL CARE DEPT. WAIKATO

CRITICAL CARE WAIKATO HOSPITAL

WORKBOOK

NAME: ______________________________

Te Hanga Whaioranga Mō Te Iwi
Building Healthy Communities

Waikato District Health Board

Section 2

Respiratory assessment

Physical assessment

A vital part of respiratory assessment is observation of respiratory rate and depth. Increased respiratory rate and shallow breaths are an important indication of respiratory distress, but also be aware that increased respiratory rate can be an indication of a non-respiratory problem such as DKA and shallow breaths can be due to pain on breathing with a problem such as rib fractures.

Pulse oximetry

Oxygen saturation is measured as a percentage and is calculated as the amount of oxygen carried by the haemoglobin compared to the amount of oxygen that could be carried.

$$\% \ O_2 \text{ saturation} = \frac{\text{Amount of } O_2 \text{ carried by Hb}}{\text{Amount of } O_2 \text{ that could be carried by Hb}} \times 100$$

Oxygen saturation measures the saturation of haemoglobin with oxygen, whereas PaO_2 measures the amount of oxygen (the partial pressure, in kilopascals) dissolved directly in the plasma. Usually around 97% of oxygen in the bloodstream is carried by haemoglobin whereas only a relatively small amount (3%) is dissolved in the plasma. Oxygen moves between haemoglobin and the plasma, and the affinity of haemoglobin for oxygen is altered by factors such as body temperature and pH as described in the previous section.

The pulse oximeter consists of a photodetector and 2 diodes which emit light at different wavelengths, one red and one infrared. The sensor and diodes are placed opposite each other with tissue in between. The oximeter works by switching on and off the photodiodes hundreds of times per second and recording the amount of light that is absorbed. The processor in the pulse oximeter then calculates the oxygen saturation using an algorithm. The number which is then displayed is calculated over the previous 3-6 seconds.

Limitations:

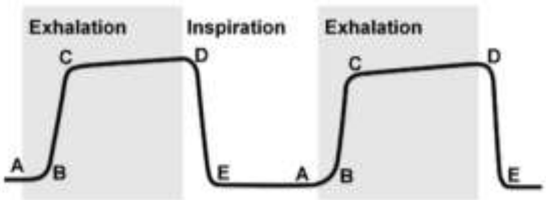
- Pulse oximetry does not measure the effectiveness of ventilation. A patient may have increased CO_2 from hypoventilation while maintaining good oxygen saturation.
- Improper placement of the probe may lead to only one of the diodes recording and this may affect the reading. It is important to ensure that the finger (or earlobe) is placed centrally between the probe hinges.
- Patient movement (e.g. shivering) may affect the reading.
- Intense daylight or fluorescent light may cause incorrect readings.
- Pulse oximeters may also be affected by patient factors such as abnormal haemoglobin (including anaemia), nail polish, pigmented skin or dye such as methylene blue. Poor limb perfusion due to vasoconstrictors will also affect readings and the accuracy of pulse oximetry has been shown to decrease in

adults where the systolic BP falls below 80mmHg. Hypothermia is another cause of limb hypoperfusion which can impair pulse oximetry accuracy.

End tidal CO_2 monitoring

The usefulness of monitoring end tidal CO_2 depends on the assumption that the expired CO_2 reading from the alveoli is similar to that of the PCO_2 in the bloodstream. The sample of expired CO_2 is used to approximate the PCO_2 of the arterial blood. Under normal conditions and in good health, end tidal CO_2 is approximately 0.3 – 0.7 kPa lower than arterial PCO_2. The accuracy of readings may be affected by water vapour or high oxygen concentrations.

The capnograph waveform usually resembles the waveform below:



The waveform (and the $EtCO_2$ value) is used to assess ET tube placement following intubation. This can be seen either on a patient monitor (in ICU) or on a portable 'EMMA' capnograph (on ICU and HDU). A 'flatline' waveform with a reading of zero CO_2 is an emergency, as this suggests that the ETT tube is in the oesophagus rather than in the trachea (assuming the capnograph is working correctly).

Chest x ray

Tissue Densities

As x-rays travel through the chest from the emitting tube to the film plate, they are absorbed to varying degrees by the tissues through which they pass (Table 1). Very dense tissue, such as bone, absorbs almost all the x-rays, leaving the film unexposed, or white. The heart, the aorta, the pulmonary vessels and the blood are moderately dense structures, appearing as grey areas on the x-ray film. These vascular structures are surrounded by air-filled lung that allows the greatest penetration of x-rays, resulting in fully exposed (black) areas on the film. Thoracic structures can be studied best by examining their borders. Two structures with the same density, when located next to each other, have no visible border, but if a structure is located next to another with a contrasting density then even subtle changes in size and shape can be seen.

Table 1: X-ray densities

Bone or metal **(White)**	**Fluid** **(Grey)**	**Air** **(Black)**
Ribs, sternum, spine	Blood	Lung
Calcium deposits	Heart	
Surgical wires or clips	Veins	

Bone or metal **(White)**	**Fluid** **(Grey)**	**Air** **(Black)**
Prosthetic valves	Arteries	
Pacemaker wires	Oedema	

Standard Views

In most institutions, a standard radiographic examination of the heart and lungs consists of posterior-anterior (PA) and left lateral films. The standard film is taken in the radiology department with the patient in an upright position; the film exposed during a deep, sustained inhalation with the x-ray tube aimed horizontally two metres from the film. This is referred to as a PA film because the beam traverses the patient from posterior to anterior.

Portable Chest Radiography

Because most patients in critical care units are too sick to go to the radiology department, chest radiographs are routinely obtained by using portable x-ray machines, with the patient sitting upright or lying supine, depending on the patient's clinical condition and the judgement of the clinician. The film plate is placed behind the patient's back and an antero-posterior (AP) projection is used, in which the x-ray beam enters from the front of the chest. For the supine film, with the patient lying flat on the bed, the x-ray tube can be only about 1 metre from the patient's chest because of ceiling height and x-ray equipment construction. This results in a lower quality film from a diagnostic standpoint, because the images of the heart and great vessels are magnified and not as sharply defined. Whenever possible, the upright film is preferred to the supine one, because it provides a more accurate image, it shows more of the lung since the diaphragm is lower, and the thoracic structures appear sharper and less magnified.

How To Read a Chest X-Ray

1. The most important factor in reading a chest x-ray is to approach an image systematically, using the same process every time.

2. Check the patient's name. Above all else, make sure you are looking at the correct chest x-ray first.

3. Read the date of the x-ray. Make special note of the date when comparing older x-rays (always look at older radiographs if available). The date provides important context for interpreting any findings. For example, a mass that has become bigger over 3 months is more significant than one that has become bigger over 3 years.

4. Note the view (usually AP in Critical Care, as explained above). Also, note whether it is erect or supine.

5. Look for markers: 'L' for Left, 'R' for Right, 'AP' for anteroposterior, etc. Note the position of the patient: supine or erect.

6. Note the technical quality of film:

- Exposure: Overexposed films look darker than normal, making fine details harder to see; underexposed films look whiter than normal, and cause appearance of areas of opacification. Look for intervertebral bodies in a properly penetrated chest x-ray. An under-penetrated chest x-ray cannot differentiate the vertebral bodies from the intervertebral spaces, while an over-penetrated film shows the intervertebral spaces very distinctly. To assess exposure, look at the vertebral column behind the heart on the frontal view. If detailed spine and pulmonary vessels are seen behind the heart, the exposure is correct. If only the spine is visible, but not the pulmonary vessels, the film is too dark (overexposed). If the spine is not visible, the film is too white (underexposed).

- Motion: Motion appears as blurred areas. It is hard to find a subtle pneumothorax if there is significant motion.

- Rotation: Rotation means that the patient was not positioned flat on the x-ray film, with one plane of the chest rotated compared to the plane of the film. It causes distortion because it can make the lungs look asymmetrical and the cardiac silhouette disoriented. Look for the right and left lung fields having nearly the same diameter, and the heads of the ribs (end of the calcified section of each rib) at the same location to the chest wall, which indicate absence of significant rotation. If there is significant rotation, the side that has been lifted appears narrower and denser (whiter) and the cardiac silhouette appears more in the opposite lung field.

7. Now go through the following (ABCDEFGHI):

Airway: Check to see if the airway is patent and midline (e.g. in tension pneumothorax, the airway is deviated away from the affected side). Look for the carina, where the trachea divides into the right and left main stem bronchi.

Bones: Check the bones for any fractures, lesions, or defects.

Cardiac silhouette: Look at the size of the heart. A normal sized cardiac silhouette should occupy less than half the chest width.

Diaphragm: Diaphragm: is one half of the diaphragm higher than the other? Is free air present beneath the diaphragm?

Effusion / empty space / expanded lungs: Look for pleural effusion and pneumothorax

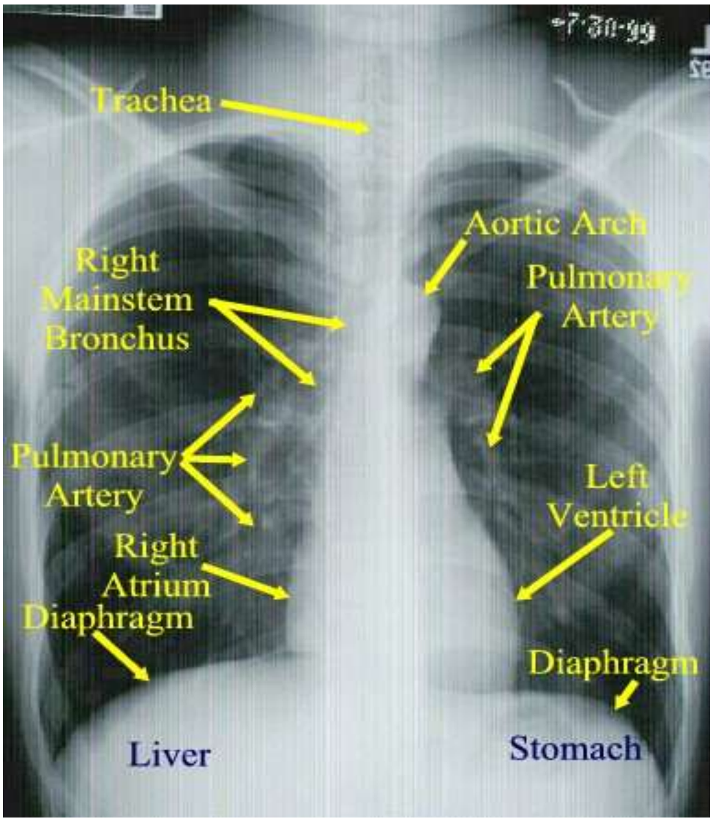
Fields of the lungs / foreign bodies: Look for symmetry, vascularity, presence of any mass, nodules, infiltration, fluid, etc. If fluid, blood, mucous, or tumour, etc. fills the air sacs, the lungs will appear radiodense (bright), with less visible interstitial markings.

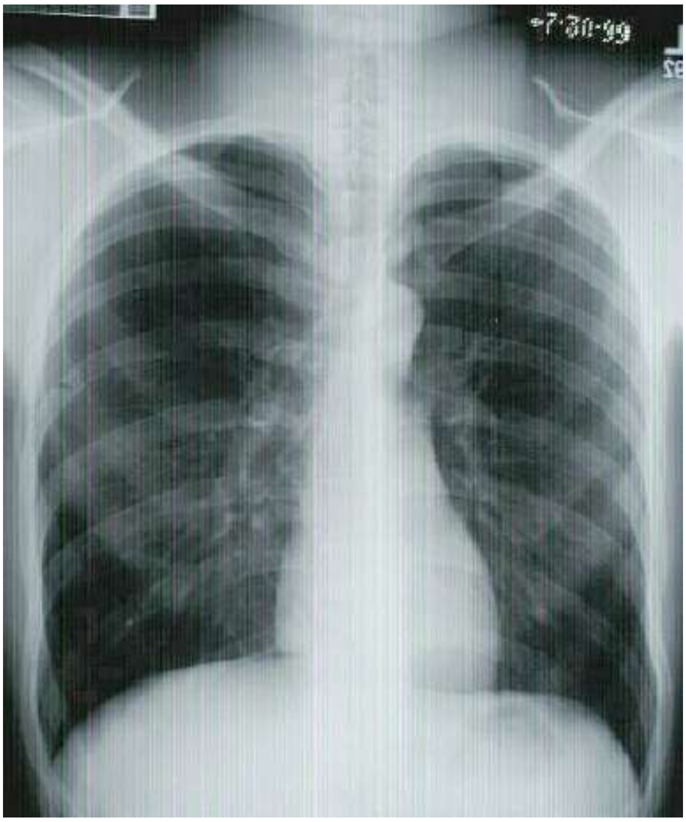
Gastric bubble: Look for the presence of a gastric bubble, just below the heart; note whether it is obscured or absent. Assess the amount of gas and location of the gastric bubble.

Hila: Look for nodes and masses in the hila of both lungs. (the hilar shadows represent the left and right pulmonary arteries). The left pulmonary artery is always more superior than the right, making the left hilum higher.

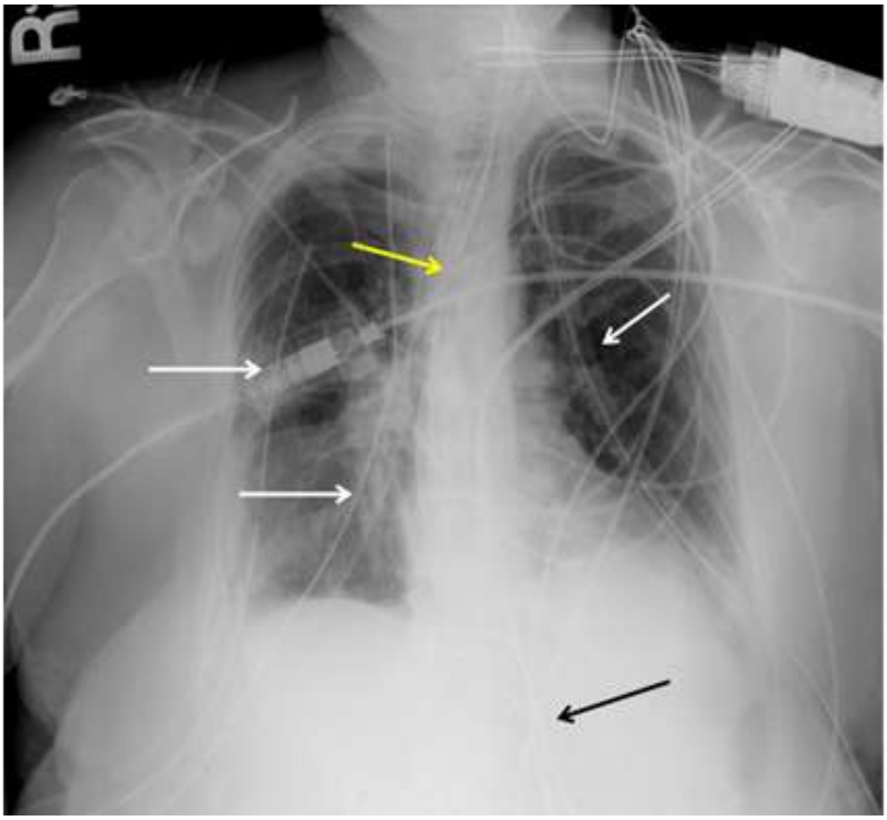
Instrumentation: Look for any tubes (e.g. endotracheal, nasogastric), CV lines, ECG leads, pacemaker, surgical clips, drains, prostheses, etc.

Normal chest x-ray





Abnormal chest x-ray



http://reference.medscape.com/features/slideshow/chest-x-ray. Slide 12

Foreign objects, such as lines and tubes, can greatly complicate a chest x-ray, but each item must be individually identified to ensure proper positioning. This AP supine chest x-ray was taken of a patient with multiple sites of trauma. Two right chest tubes and 1 left chest tubes are present (white arrows). The tip of the endotracheal tube (yellow arrow) is noted to be in line with the air in the trachea and above the carina. The ideal position is between the clavicular heads and the carina. The nasogastric tube is seen overlying the stomach (black arrow). The ECG wires and leads crossing the chest represent visual distractions that can lead to diagnostic errors. All wires and tubes that are outside the patient should be carefully repositioned to the side of the patient before taking the x-ray. In some cases, repeat x-rays are required to confirm line or tube positioning.

Chest Auscultation

To listen for breath sounds, follow an organized, systematic pattern. Listen for at least one full breath in each location.

Move the stethoscope from side to side, in the same position on each side, working your way down the chest. Repeat the pattern on the back if possible. This method is used to compare and contrast what you are hearing from one side to the other.

Start by listening for bronchial breath sounds over the trachea. These are loud, high-pitched, harsh, and hollow. To hear them, listen with the diaphragm of your stethoscope just below the cricoid cartilage and above the supraclavicular notch as your patient takes a deep breath.

Typically, the inspiratory phase is about half the duration of the expiratory phase. If you are listening to an intubated patient, expect to hear breath sounds over each bronchus. If you do not, the endotracheal tube may have slipped into one of the bronchi and only one lung is being aerated. Notify the registrar / nurse in charge immediately if this occurs.

Bronchial and bronchovesicular breath sounds provide information about the middle and upper airways of the patient's lungs. Although many common pulmonary problems occur in the lobes of the lungs, the patency of the upper airways is vital. If the patient is intubated, has recently been extubated, is asthmatic, has a tracheostomy, has had upper-airway trauma or surgery, has had a pneumonectomy or a collapsed lung, or has had any condition involving tracheal or bronchial irritation, you may need to pay special attention to these breath sounds as heard over the precordial area.

In addition, be sure to listen for additional breath sounds. Adventitious breath sounds are divided into two categories: (1) crackles (noncontinuous sounds) and (2) wheezes (continuous sounds).

Crackles and Wheezes

Crackles are distinct, noncontinuous sounds of two types: (1) fine and (2) coarse. Fine crackles are thought to be caused by two mechanisms: One type of crackling sound occurs when alveoli in the lung bases “pop” open during inspiration, as with atelectasis or pulmonary fibrosis. The other type of crackle occurs in patients with pulmonary oedema, probably from air bubbling through fluid. When you listen, you will hear crinkling, popping, or even sounds like a slurping straw, usually at the beginning or end of inspiration.

Typically, crackles that result from fluid are ‘dependent’. Fluid settles at the lowest portion of the lungs and the level ascends as the condition worsens. If your patient has been sitting upright, expect to hear them in the lung bases. Alternatively, if your patient has been lying on one side for several hours, the fine crackles will be more prominent in the lung on that side. In the final stages of heart failure, auscultation typically reveals continuous crackles, along with sibilant and sonorous wheezes (the so-called ‘washing-machine chest’).

If the patient has diffuse interstitial fibrosis, you may hear dry crackles that resemble the sound of crumpling cellophane or Velcro.

When listening for coarse crackles, loud bubbling or gurgling sounds will be may be during both inspiration and expiration, but more commonly on expiration. These sounds are heard primarily in the trachea and bronchi, but they are also heard in the lower lobes of the lungs.

Expect to hear coarse crackles if the patient has pneumonia or bronchitis. If the patient cannot easily cough up secretions (e.g. they may have an ETT or a tracheostomy) or they have a loose, productive cough, you will hear coarse crackles with or without a stethoscope. Often they can be remedied by suctioning, having your patient cough, respiratory treatments, or bronchodilators.

Usually, coarse crackles will clear or diminish after coughing. Fine crackles caused by fluid or secretions will remain unchanged.

Sibilant (meaning ‘hissing’) wheezes are prolonged, high-pitched, musical or whistle sounds resulting from rapid airflow through narrowed airways. If you hear them bilaterally, they may indicate bronchospasm. They may or may not be associated with crackles and are not affected by coughing.

Other Breath Sounds

Stridor, a loud musical sound produced by upper airway obstruction, is heard commonly during childhood croup and does not require a stethoscope. It is typically inspiratory, but it becomes inspiratory and expiratory as the airway becomes more obstructed.

To differentiate stridor from wheeze, listen over the trachea below the cricoid cartilage on one side of the neck. Stridor sounds loudest in this location, whereas wheezing is loudest in the chest.

Less commonly, you may encounter such sounds as friction rubs, referred breath sounds, and a mediastinal crunch. A pleural friction rub occurs during or at the end of inspiration and has a high-pitched, scratchy sound. Different from a pericardial rub, a pleural rub is heard with inspiration and disappears after expiration.

To determine whether a rub is pleural or pericardial, listen over the patient's heart while they hold their breath. If you hear a rub with each heartbeat, the rub is pericardial, not pleural.

Referred breath sounds are noises heard over an area where you would not normally expect to hear anything, such as on the side where your patient had a pneumonectomy or a lobectomy, or above a tracheostomy. Because sound travels through fluid and tissue, you may hear a faint inspiratory or vesicular sound over that area.

Arterial Blood Gas Analysis

Arterial blood gas (ABG) analysis is an effective way to evaluate acid-base balance.

1. **pH:** Measures the hydrogen ion concentration to reflect the acid-base status of the blood. Values reflect whether arterial pH is normal (7.40), acidic (<7.40), or alkalotic (>7.40). If there is more than one acid-base imbalance at work then the pH will reflect the process that is in control.

   Normal range = 7.35-7.45

2. **Partial pressure of CO_2** in arterial blood ($PaCO_2$): This is the respiratory component of acid-base regulation; adjusted by changes in the rate and depth of ventilation. Hypercapnia ($PaCO_2$>6 kPa) indicates hypoventilation and respiratory acidosis. Hyperventilation results in a $PaCO_2$ less than 4.6 kPa and respiratory alkalosis. When there is a metabolic acid-base disturbance, respiratory compensation occurs rapidly. Therefore, if any abnormality in

$PaCO_2$ exists, it is important to analyse the pH and HCO_3 parameters to determine whether the alteration in $PaCO_2$ is the result of a primary respiratory disturbance or a compensatory response to a metabolic acid-base abnormality.

Normal range = 4.7 – 6 kPa

3. **HCO_3 (bicarbonate)**: Bicarbonate (HCO_3) is the major renal component of acid-base regulation. It is excreted or regenerated by the kidneys to maintain a normal acid-base balance. A decreased HCO_3 level (<22 mmol/L) is indicative of metabolic acidosis (*or*, compensation for respiratory alkalosis). An elevated HCO_3 level (>26 mmol/L) either reflects metabolic alkalosis, due to a primary metabolic disorder, or is a compensatory mechanism in response to respiratory acidosis.

   Normal range = 22-26 mmol/L

   The pH and $PaCO_2$ parameters need to be considered to determine whether the alteration in HCO_3 is the result of a primary metabolic disturbance or is a compensatory response to a respiratory acid-base abnormality.

4. **Base excess or deficit (BE)**: BE is a way of looking at the metabolic component of an acid-base problem, without taking the respiratory component/compensation into account. If the number is negative (e.g. minus 6), this would normally indicate a metabolic acidosis. If the number is positive (e.g. plus 6), this would normally indicate a metabolic alkalosis. It is a useful way to assess a **trend** in a patient's acid-base balance. Here is an example explaining why:

   Let's say we have a very sick patient, with severe pneumonia and sepsis, with a combined metabolic and respiratory acidosis. They have a **low** pH, a **low** HCO_3 and a **high** $PaCO_2$. Now, let's say we put them on a ventilator (or, in HDU, on BIPAP). We could reduce the patient's $PaCO_2$ by improving/increasing their ventilation. This would then decrease the pH and a person looking at this improvement in their pH might think that the patient's underlying metabolic acidosis was improving, but really we have only made the acidosis appear better by manipulating the $PaCO_2$. To avoid being deceived by this, medical staff will often look at the BE. The general trend in the BE (whether or not the BE is steadily becoming more negative), gives them a good impression of whether the patient's metabolic acidosis is improving or worsening.

   Normal range = plus 2 to minus 2

5. **Partial pressure of oxygen** in arterial blood (PaO_2): Has no primary role in acid-base regulation (if it is within normal limits). The presence of hypoxaemia, with a PaO_2 less than 8kPa can lead to anaerobic metabolism, resulting in lactic acid production and metabolic acidosis. Hypoxaemia may also cause hyperventilation, resulting in respiratory alkalosis.

Normal range = 10.5 – 13 kPa

6. **Oxygen saturation:** Measures the degree to which haemoglobin is saturated by oxygen. It can be affected by changes in temperature, pH, and $PaCO_2$. When the PaO_2 falls below 8 kPa, there is a large drop in saturation. Pulse oximetry is often used for continuous O_2 saturation monitoring but is only accurate for saturations of more than 80% and is affected by factors such as decreased perfusion, vasoconstrictive agents and nail polish. In the critical care area it is often helpful to compare the oxygen saturation from the pulse oximeter with the value on the ABG.
Normal range = 96-100%

Normal values: **pH 7.35-7.45** **PO_2 10.5-13 kPa** **PCO_2 4.7- 6 kPa** **HCO_3 22-26 mmol/L**			
pH	**$PaCO_2$**	**HCO_3**	**=**
Acidaemia (pH low)	High	Normal/High	Respiratory acidosis
Acidaemia (pH low)	Low	Low	Metabolic acidosis
Alkalaemia (pH high)	Low	Normal/Low	Respiratory alkalosis
Alkalaemia (pH high)	High	High	Metabolic alkalosis

Step by step guide to Arterial Blood Gas Analysis

Step one: Determine whether the pH is normal. If it deviates from 7.40, note how much it deviates and in which direction. For example, pH higher than 7.45 indicates alkalaemia; pH less than 7.35 indicates acidaemia. Is the pH in the normal range of 7.35 to 7.45, or is it in the critical range of greater than 7.55 or less than 7.20?

Step two: Check the $PaCO_2$. If it deviates from 4.7 - 6 kPa, how much does it deviate and in which direction? Does the change in $PaCO_2$ correspond to the direction of the change in pH? The pH and $PaCO_2$ should move in opposite directions. For example, as the $PaCO_2$ increases, the pH should decrease (acidosis); as the $PaCO_2$ decreases, the pH should increase (alkalosis).

Step three: Determine the HCO_3 value. If it deviates from 22-26 mmol/L, note the degree and direction of deviation. Does the change in HCO_3 correspond to the change in pH? The HCO_3 and pH should move in the same direction. For example, if the HCO_3 decreases, the pH should decrease (acidosis); as the HCO_3 increases, the pH should increase (alkalosis).

Step four: If both the $PaCO_2$ and HCO_3 are abnormal, which value corresponds more closely to the pH value? For example, if the pH reflects acidaemia, which value also reflects acidaemia (an increased $PaCO_2$ or a decreased HCO_3?). The value that more closely corresponds to the pH and deviates more from normal indicates the primary disturbance responsible for the alteration in pH. A mixed metabolic-respiratory disturbance or compensatory elements may be present when both HCO_3 and $PaCO_2$ are abnormal.

Step five: Check PaO_2 and O_2 saturation to determine whether they are decreased, normal, or increased. Decreased PaO_2 and O_2 saturation can lead to lactic acidosis and may signal the need for increased concentrations of oxygen. Conversely, a high PaO_2 may be indicative of the need to decrease delivered concentrations of O_2.