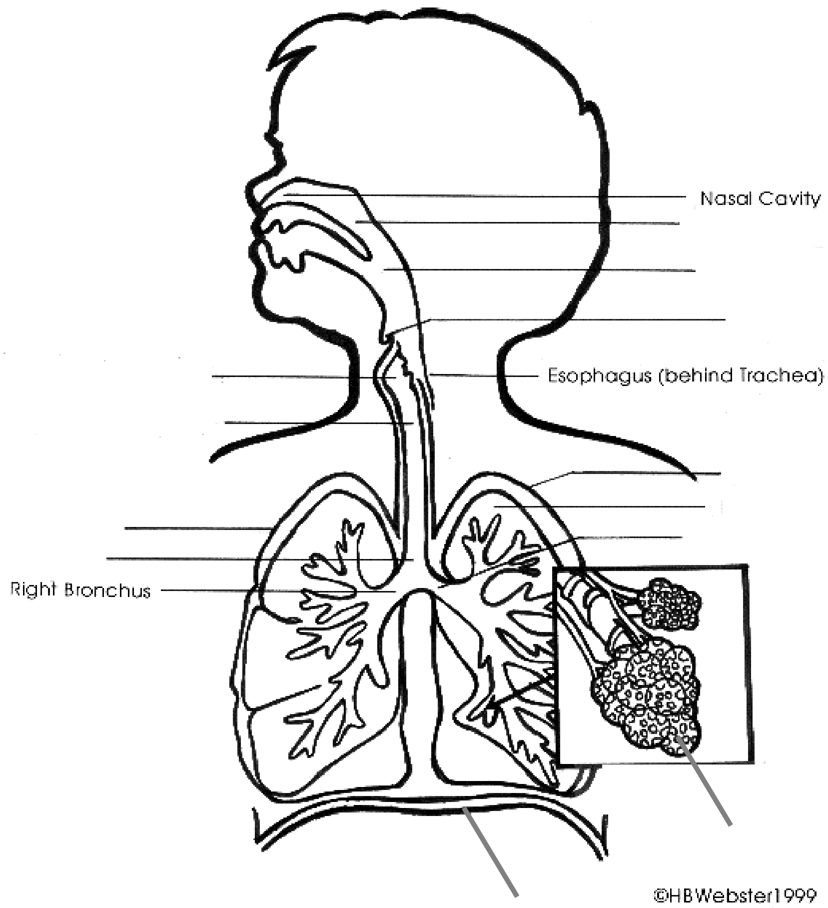
AN INTRODUCTION TO RESPIRATORY PHYSIOLOGY

LEARNING PACKAGE

1. PRINCIPLES OF RESPIRATORY PHYSIOLOGY

1.1 Anatomy of the respiratory system

Please label the following diagram



1.2 Functions of the respiratory system

The major functions of the respiratory system are to **supply oxygen and eliminate carbon dioxide** from the body. In addition to the vital function of gas exchange the respiratory system also fulfils secondary functions of:

- **Acid base regulation**
- **Acts as a blood reservoir**
- **Acts as a filtering mechanism**
- **Metabolism**

1.3 The control of ventilation

The volume and frequency of ventilation is regulated by impulses originating from the respiratory bodies in the medulla oblongata and pons. These impulses are conveyed to the respiratory muscles by the phrenic and intercostal nerves. These impulses are governed by information received from various receptors located in the body. There are two types of receptors namely central and peripheral. The central receptors are located within the close proximity to the respiratory centre and are mainly reactive to changes in pH in the cerebrospinal fluid secondary to fluctuations in carbon dioxide levels. A high pH (low CO_2) diminishes breathing while a low pH (high CO_2) stimulates breathing. The peripheral receptors located in the carotid bodies are reactive to both changes in pH and by hypoxia,

In patients with chronic lung disease the sensitivity of the respiratory centre to an elevated $PaCO_2$ may become diminished over a period of time due to renal compensation causing an elevated plasma HCO_3^- and CSF being excreted with an elevated HCO_3^-. This causes the CSF pH to be close to normal despite an elevated $PaCO_2$. The impulse to stimulate breathing is then governed by oxygen levels. As the PaO_2 decrease the rate and depth of respiration is increased.

Question: We are always told to give Patients with CAL low flow oxygen. Provide a brief explanation of why this is so?

Activity Complete the following table

	Normal respiratory Rate/min
Adult	
Child aged 4 years	
Infant aged 12months	

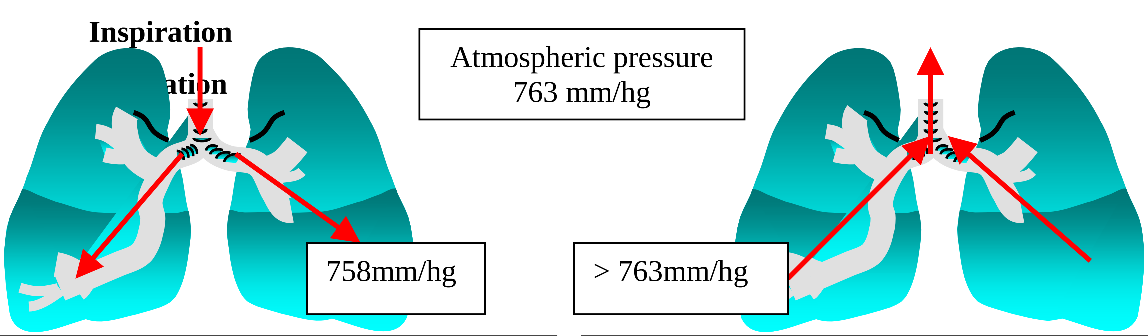
1.4 Pulmonary Ventilation: Pleural Pressures.

The lungs and chest wall are separated by the parietal and visceral pleura. Between the two pleura is the interpleural space. The pressure within the interpleural space is usually negative due to the tendency of the lungs to collapse and the chest wall to expand. It is this negative interpleural pressure that keeps the alveoli open.

In the intact chest the lungs move as the chest wall moves because the maintenance of a pressure in the interpleural space that is negative with respect to the alveoli pressure. As the thoracic dimensions increase pleural pressure is reduced which causes the lungs to increase in volume (inspiration)- as the thoracic dimensions decrease pleural pressure and alveolar pressure is increased causing gas flow out of the lungs (expiration)

This type of ventilation is referred to as negative pressure ventilation, as the pressure inside the lungs is never above atmospheric pressure in normal respiration.

Pulmonary Pressures in respect to room air



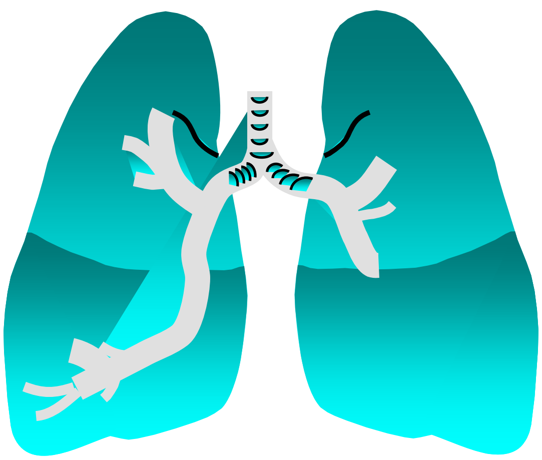
During inspiration thoracic expansion causes pressure in the lungs to fall to approx 758mm/hg, hence air is sucked into the lungs

During expiration thoracic size is reduced hence increasing the pressure in the lungs to > 763mm/hg and air is expelled

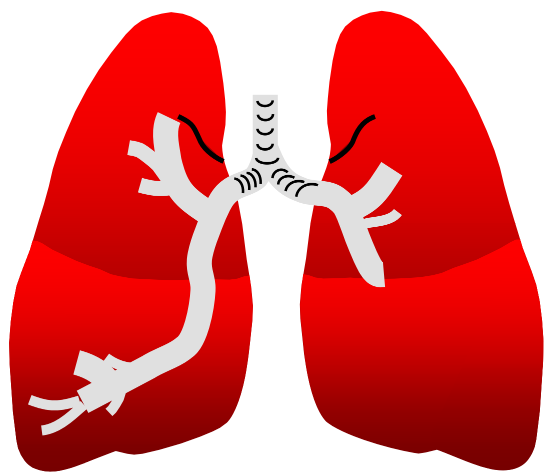
Question: Intercostal catheters are inserted to maintain interpleural pressures and inflate collapsed lungs. With these functions in mind:

- When should the chest drain be clamped
- What is The purpose of the underwater seal
- What is The purpose of low suction
- What is The relevance of bubbling and oscillation

1.5 Ventilation-Perfusion distribution



Ventilation in the lungs for a normal upright subject. The darker blue indicates increased ventilation that is towards the apices due to gravity

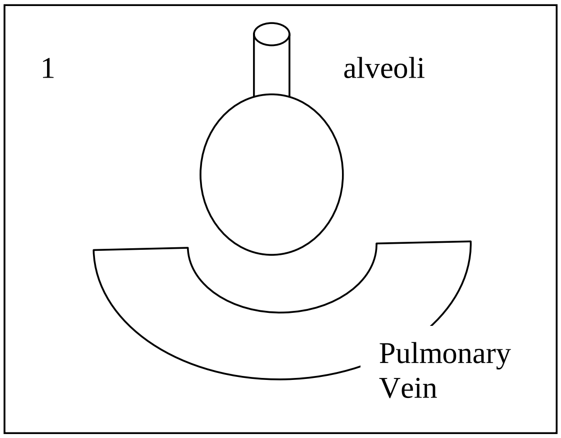


Perfusion in the upright subject is generally preferential to the bases again due to gravity. On the diagram the darker red indicates this.

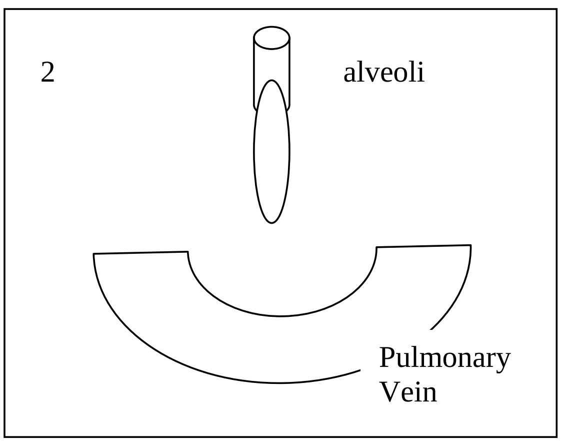
As the previous diagram indicates both ventilation and perfusion are not evenly distributed throughout the lungs, with distribution being dependent on hydrostatic pressures. In the normal upright subject this means that ventilation and perfusion is optimal in the mid zones of the lungs. The goal of many respiratory therapies is to improve the relationships between ventilation and perfusion, since many disease states act to cause an alteration in this relationship.

1.5.1 Ventilation perfusion relationships

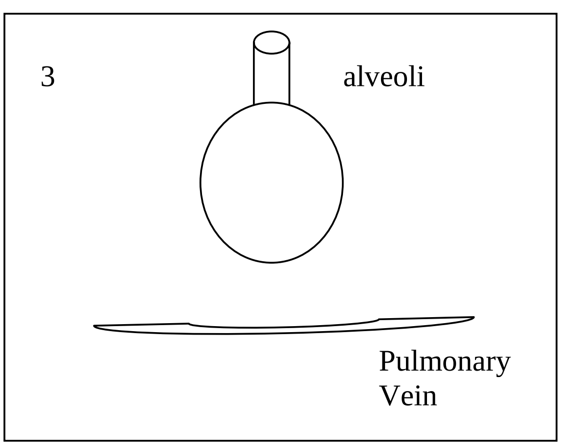
The following diagrams show some common ventilation perfusion mismatches. In the space provided indicate which disease states could cause each.



- Normal lung unit, receiving normal ventilation and perfusion.



- Shunt Unit, not ventilated but receiving normal perfusion.
- Possible causes?
- ______________________________
  ____
  ____
  ____
  ____

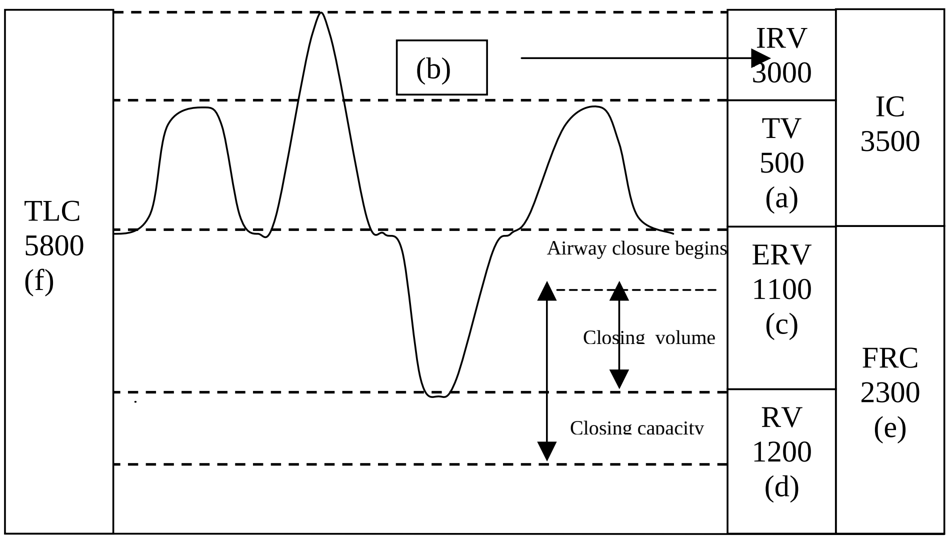


- Deadspace unit ventilated but not perfused.
- Possible causes?
- ______________________________
  ____
  ____
  ____

Question. Utilising the information on the distribution of ventilation and perfusion, what would be the ideal position for an elderly patient who presents with left lung collapse? Why

1.6 Adult Respiratory Volumes and Capacities

Complete the blanks by referring to the following diagram and any anatomy & physiology text, all numbers are reflective of mls (ref Marieb 1992, pp742-743)



The amount of air that moves into the lungs with each inspiration is called the ______________ ______________(a) The air inspired with a maximal inspiratory effort in excess of the normal inspiratory volume is the ______________ ___________ ___________ (b). The volume expelled during expiration in excess of the normal respiratory volume is the __________________ ___________ _____________(c), the air left in the lungs after a maximal expiratory effort is the _________________ _____________ (d). The combination of these volumes is referred to as the (e)____________ _______________ _______________. The sum of all lung volumes is the _____________ _________________ ____________________ (f)

Normal Values

Using the information given provide normal values for each value

a____

b____

c____

d____

e____

f____

Knowledge of these values is important when we start looking at respiratory function tests. For example spirometry is a common test used to assess lung function. The most common measures being FEV_1 and FVC. FEV_1 refers to the amount of expiratory volume expelled in 1 second. While FVC as you have already seen refers to the forced vital capacity, on a spirometer this is measured over six seconds. In the normal subject at least 75% of the FVC should be expelled in the first second, which we measure as $FEV_{1.}$ Spirometry is then used to ascertain changes in these values due to pathological conditions.

For example in asthma a condition characterised by acute airway constriction, the expected spirometry findings would be reduced FEV_1 and FVC due to inability to fully inflate or deflate the persons lungs secondary to the narrowed airways. However once the attack had resolved either spontaneously or secondary to bronchodilators, it would be expected that these values would return to normal.

Conversely in conditions that are chronic in nature such as CAL, you would expect the FEV_1 to be reduced while the FVC remains normal. With therapy having little effect on the results.

2. Lung Mechanics: resistance and compliance

The mechanical characteristics of the lung greatly influence both normal lung function and pulmonary disability. The two major factors involved in mechanics are lung compliance and resistance.

2.1 Compliance

In health, inspiration is an active process, accomplished through the expansion of the lungs and thorax. The ease, with which the lungs and thorax can be expanded or distended, is referred to as compliance. Total lung compliance thus depends not only on the elasticity of the lung tissue but also on that of the thoracic cage.

Compliance determines the change in volume for a given change in pressure. For example if a patient is able to sustain a large increase in tidal volume with a small fall in pleural pressure then they have compliant lungs.

Compliance is reduced by any factor that:

- Reduces the natural elasticity of the lung, such as fibrosis or interstitial oedema.
- Reduces the total number of functional alveoli such as atelectasis or airway obstruction
- Increases the stiffness of the chest wall eg) splinting because of pain
- Decreases in the stiffness of the chest wall eg post sternotomy resulting in decreased FRC
- Reduces the ability of the thorax to increase in volume eg abdominal distension

Compliance is therefore a relationship between volume and pressure and can be estimated by dividing the change in volume by the change in pressure ie)

Compliance =Change in volume/Change in pressure

2.2 Resistance

Resistance refers to impedance to flow. For gas to flow a pressure difference must exist between two ends of a tube. The relationship between the driving pressure and the resultant flow is termed the resistance. Airway resistance is the pressure difference between the alveoli and mouth divided by the flow rate.

Resistance to flow may be either inspiratory or expiratory. Factors that increase resistance include:

- Bronchial tone
- Sputum

- Oedema
- External breathing circuits eg) ETT Tube

Airflow obstruction can lead to gas trapping resulting in hyperinflation of the alveoli (auto-PEEP). Possible effects of this are:

1. Tidal volume may cycle close to total lung capacity decreasing compliance and increasing the risk of barotrauma.
2. Increase in work of breathing
3. Decreased preload and cardiac output (see definition in Cardiac learning package)

3. SUPPORT FOR OXYGENATION

Generally speaking oxygen and positive pressure (CPAP/PEEP) are used to treat problems with oxygenation whilst mechanical ventilatory support is used to treat ventilatory failure.

Hypoxaemia caused by the following is responsive to oxygen therapy

- Hypoventilation
- Reduced ability to transfer O_2 across the alveoli/capillary membrane eg)pulmonary oedema
- Ventilation –perfusion inequality

Oxygen therapy should always involve the consideration of other factors that determine oxygen delivery:

- Cardiac output
- Haemoglobin
- Blood distribution

3.1 Oxygen administration

Method	Rate of Flow l/min	Approx O_2 %
NON-rebreather	8 10-15	60 60-70
Nasal cannulae	1 2 3 4 5 6	23 25 30 34 40 44

Simple mask	5 6 8	40 45-50 55-60
Disposable infant head box	**10** **15**	**up to 50** **over 50**

Oxygen is a drug as such there should always be a medical order for the prescribed dose. The nurse should also be vigilant in patient monitoring to ascertain whether the dosage of the drug (oxygen) is appropriate.

Question: You are ordered to apply 6 lmin of oxygen to a patient via a simple mask. What observations would you take to ascertain if this is the appropriate dosage ?

4. PAEDIATRIC PATIENTS: SPECIAL CONSIDERATIONS.

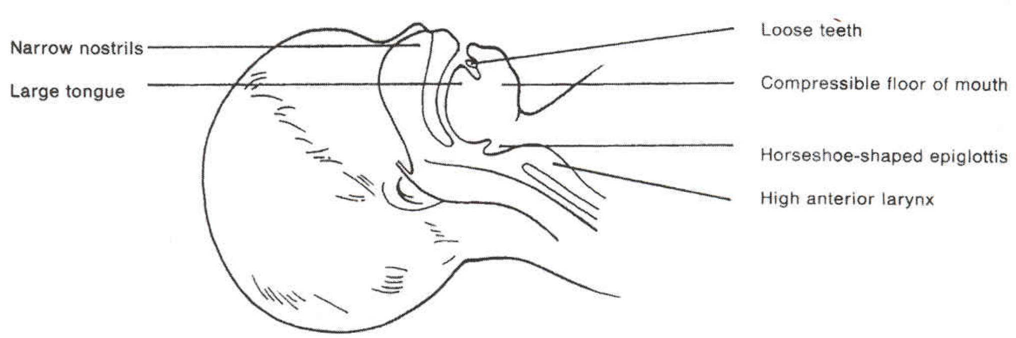
Children have unique anatomical and physiological differences. Remember:

- size and relative body proportion change with age
- care regimes and management is related to age and weight
- children have unique psycohological needs

As the child grows and their weight increases the shape and proportion of various organs change.

Note: By approximately 8 years of age children's airway anatomy and physiology approximates that of adults.

Airway Differences:



Summary of significant upper airway anatomy for a child.

- Head is large and the neck is short, tending to cause neck flexion
- Infants less than 6 months old are obligate nasal breathers
- Diaphragmatic breathers- anything that impedes diaphragmatic contraction can lead to respiratory distress
- Intercostal muscles not fully developed these muscles function to stabilize not lift the chest wall
- Large tongue/small mouth
- Shorter and softer trachea, overextension or flexion may cause tracheal compression
- Narrower airways which are easily obstructed by secretions
- Epiglottis is horseshoe shaped and projects posteriorly at 45˚
- Larynx high and anterior
- Cricoid ring is the narrowest point of the airway
- Easily fatigued
- Ribs horizontally in orientation – this reduces the efficiency of ventilation during periods of respiratory distress up to approximately the preschool age
- Cartilagenous compliant chest wall – compromising the child’s ability to maintain functional residual capacity or increase their tidal volume when experiencing respiratory distress
- Chest wall very thin – transmit sounds more readily

References

Advanced Paediatric Life Support. The Practical Approach. *(2005)* BMJ Publishing Group.

Hazinski MF., (1992) Nursing Care of the Critically Ill Child. Second Edition. Mosby Year Book St Louis.