# respiratory physiology

## factors shifting O2 dissociation curve left

| Factors decreasing P50 (curve shifts to left) |
|---|
| Hypothermia |
| Increased pH (alkalaemia) |
| Decreased $PCO_2$ |
| Decreased 2, 3 DPG |
| Fetal haemoglobin |
| Carboxyhaemoglobin |
| Methaemoglobin |

## factors shifting O2 dissociation curve right

| Factors increasing P50 (curve shifts to right) |
|---|
| Hyperthermia |
| Decreased pH (acidaemia) |
| Increased $PCO_2$ (Bohr effect) |
| Increased 2, 3 DPG |

## oxygen cascade

| | mmHg |
|---|---|
| Inspired air | 150 |
| Alveolar | 103 |
| Arterial | 100 |
| Capillary | 51 |
| Tissue | 20 |
| Mitochondrial | 1–20 |

## pulmonary oxygen transfer

- the best measure of pulmonary gas transfer is by the multiple inert gas elimination technique, although this is not normally available at the bedside
- the method has identified V/Q mismatch and intrapulmonary shunt as the two main causes of reduced pulmonary oxygen transfer in critical illness
- intrapulmonary shunt predominates in the acute respiratory distress syndrome, in lobar pneumonia & after cardiopulmonary bypass, whereas V/Q mismatch is more prominent in chronic lung disease

(1) A-a gradient
- part of APACHE-II score & is calculated using the alveolar gas equation
- hypoxaemia with raised A-a gradient can be due to:
  (i) alveolar hypoventilation (elevated PACO2)
  (ii) low FiO2 or altitude
- hypoxaemia with a raised A-a gradient can be due to:
  (i) diffusion defect (rare)
  (ii) V/Q mismatch
  (iii) shunt (intracardiac or intrapulmonary)
  (iv) increased arteriovenous oxygen extraction
- drawbacks of A-a gradient include:
  (i) it is both FiO2 & age dependent
  (ii) for lungs with an unchanging intrapulmonary shunt the A-a gradient alters with FiO2
  (iii) in constant V/Q mismatch the relationship between the A-a gradient and FiO2 is even more complex

(2) PaO2/FiO2 ratio
- PF ratio forms part of the definition of acute lung injury and ARDS & it is also an input in SAPS 2 & lung injury scoring systems
- at sea level normal value is >500mmHg; unlike the A-a gradient it cannot distinguish between alveolar hypoventilation and other causes of hypoxaemia
- drawback are:
  (i) in ARDs PF ratio is unreliable unless estimated when FiO2>0.5, PaO2<100mmmHg, and CaO2-CvO2 is constant
  (ii) alters with altitude
  (iii) alters when FiO2 is varied in lungs with VQ mismatch
  (iv) alters when there are fluctuation in CaO2-CvO2 (eg in sepsis)

## pulmonary oxygen transfer - tension based indices

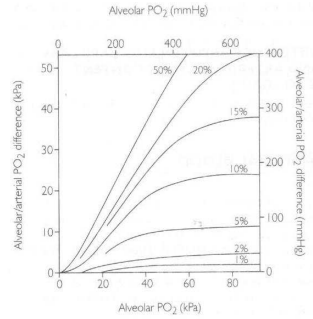


**Fig. 11.1** Effect of varying $FiO_2$ (via alveolar $PO_2$) on A-a gradient with different degrees of intrapulmonary shunt.

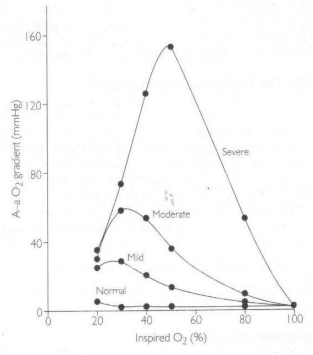


**Fig. 11.2** Effect of varying $FiO_2$ on A-a gradient with mild, moderate and severe V/Q mismatch. No allowance has been made for absorption atelectasis or alterations in hypoxic pulmonary vasoconstriction. (Figures 11.2 and 11.3 reproduced

## pulmonary oxygen transfer - content based indices

(1) Venous admixture (Qs/Qt)
- a calculation derived from a three compartment model of the lung, the three compartments consisting of the ideal compartment (V/Q = 1), the perfused but unventilated alveoli (V/Q = 0) & the alveolar dead space (V/Q is infinite)
- venous admixture is the proportional of mixed venous blood flowing through the theoretical shunt compartment where V/Q = 0
- calculation is: Qs/Qt = [Cc'O2 - CaO2] / [Cc'O2 - CvO2]
where Cc'O2, CaO2 & CvO2 represent pulmonary end-capillary, arterial & mixed venous oxygen respectively (Cc'O2 is estimated from the PAO2 by the alveolar gas equation & saturation is calculated from HbO2 dissociation curve
- advantages of this technique are:
  (i) it is unaffected by barometric pressure
  (ii) it is unaffected by alveolar hypoventilation
  (iii) provided that intrapulmonary shunt is the dominant pathology it is stable across the entire range of FiO2 despite variations in CaO2-CvO2
  (iv) when determined at FiO2 = 1, venous admixture is a measure of true shunt
- disadvantages of this technique are:
  (i) need for a PA catheter
  (ii) highly variable with FiO2 in V/Q mismatch

(2) VQI: the dual oximetry method:
- by assuming pulmonary capillary saturation is 1, the equation for venous admixture canbe simplified. Qs/Qt calculated in this way is termed VQI
- the advantage of this technique is that VQI can be continuously monitored by pulse oximetry with mixed venous oximetry

(3) Estimated shunt fraction:
- estimated shunt fraction relies of CaO2-CvO2 being assumed to be constant (which it is not in critical illness

## factors that decrease vital capacity

| Decreased muscle strength |
|---|
| Myopathy |
| Neuropathy |
| Spinal cord injury |
| **Increased lung elastance** |
| Pulmonary oedema |
| Atelectasis |
| Pulmonary fibrosis |
| Loss of lung tissue |
| **Increased chest wall elastance** |
| Pleural effusion |
| Haemothorax |
| Pneumothorax |
| Kyphoscoliosis |
| Obesity |
| Ascites |
| **Reduced FRC** |
| Atelectasis |
| Premature airway closure (e.g. COPD) |

## Hb dissociation curve

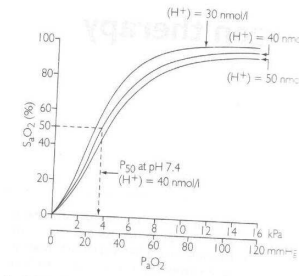


**Fig. 22.1** Hb oxygen dissociation curve. Normal curve at 40 nmol/l ($H^+$) and shifts to left and right. P50 = tension at 50% saturation.

## lung volumes & capacities

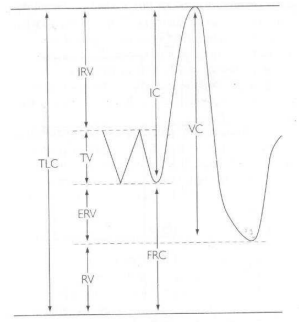


**Fig. 28.1** Lung volumes and capacities. TLC, total lung capacity; IRV, inspiratory reserve volume; TV, tidal volume; ERV, expiratory reserve volume; RV, residual volume; IC, inspiratory capacity; FRC, functional residual capacity; VC, vital capacity.

## O2 flow through masks

| Oxygen flow rate (l/min) | Approximate $FiO_2$ |
|---|---|
| 4 | 0.35 |
| 6 | 0.50 |
| 8 | 0.55 |
| 10 | 0.60 |
| 12 | 0.65 |
| 15 | 0.70 |

## O2 from various devices

| Apparatus/device | Oxygen flow (l/min) | Concentrations (%) |
|---|---|---|
| Nasal catheters | 2–6 | 25–40 |
| Semi-rigid mask (e.g. MC, Edinburgh, Hudson, Harris) | 4–15 | 35–70 |
| Venturi-type mask | | |
| individual concentration masks | 24, 28, 35 | |
| interchangeable entrainment discs | 6–12 | 40, 50, 60 |
| Soft plastic masks (e.g. Pneumask, Polymask, Oxyaire) | 4–15 | 40–80 |
| Ventilators | varying | 21–100 |
| Anaesthesia circuits | varying | 21–100 |
| CPAP circuits | varying | 21–100 |
| Plastic head hood | 4–8 | 30–50 |
| Oxygen tent/cot | 7–10 | 60–80 |
| Incubator | 3–8 | up to 40 |

## pathological flow-volume loops

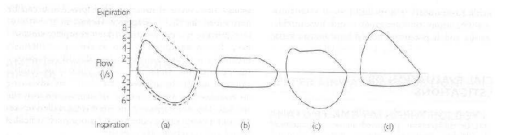


**Fig. 23.3** Flow–volume loops. Patterns resulting from different pathological lesions: (a) lower airway obstruction (e.g. chronic obstructive pulmonary disease or asthma); (b) fixed, non-variable upper airway obstruction (e.g. fibrous ring in trachea); (c) variable upper airway obstruction, intrathoracic (e.g. tumour in the lower trachea); (d) variable upper airway obstruction, extrathoracic (e.g. vocal cord tumour or paralysis).

## alveolar gas equation

PAO2 = [FiO2 X (760mmg-47)] - PaCO2 / 0.8