Gas Exchange Between Atmosphere and Tissues

• Case Study – Mrs. S from previous case study, suffering from a severe asthma attack

  – Patient taken to ICU, ventilated with an Ambu-bag and oxygen from a portable oxygen tank

  – ABG #1

    • pH 6.92
    • PaCO₂ 122 mmHg (normal, 32 - 48)
    • PaO₂ 161 mmHg (normal, 83 - 108)
    • SaO₂ 98%
    • [HCO₃⁻] 25 mEq/L (normal, 22 - 29); lactic acidosis
    • Base excess −12 mEq/L (> +3 Metabolic Alkalosis - < -3 Metabolic Acidosis)

  – Severe acidosis indicated

  – When asked about bicarbonate by a firefighter, Dr. declined in this case
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- Decided to place an endotracheal tube, which she bit through and destroyed the tube, administered Valium (diazepam) intravenously.

- Once endotracheal tube was in place, ventilated with an Ambu-bag and gurgling sounds in the stomach were heard, realized that they were in the wrong tube!

- Patient becoming more animated, more valium may affect the respiratory center, called for respiratory specialist, continued to ventilate with Ambu-bag.

- Also administered aminohyline, hydrocortisone, erythromycin intravenously via a drip.

- Specialist arrived, decided to use morphine instead of valium since an antidote can be used if severe reactions occur (Naloxone).
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- Endotracheal tube was inserted and hooked to a ventilator set to deliver
  
  - TV 650 ml
  - 30 resp/min
  - FiO₂ 100%
  - Peak pressure measured 90 cmH₂O

- Albuterol was poured down the tracheal tube, an x-ray was taken along with an order for ABG’s in 20 minutes

- ABG’s #2
  
  - pH 7.34 [6.92]
  - PaCO₂ 46 mmHg [122]
  - PaO₂ 65 mmHg [161]
  - SaO₂ 91% [98]
  - [HCO₃⁻] 25 mEq/L [25]
  - Base excess –1.3 mEq/L [-12]
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- Patient became more conscious, responded to questions by nodding, eyes appeared to be seeing

- $\text{PaO}_2$ was still low (should be around 100), concern arose as to if trache tube might be blocking air flow into the left lung, x-ray was inconclusive, Dr. ordered that trache tube be lifted approximately 1.5 inches and another set of ABG’s be taken

- ABG’s #3 – $\text{PaO}_2$ can’t be read, must be too high since $\text{SaO}_2$ is 100%

  - pH 7.5
  - $\text{PaCO}_2$ 24 mmHg
  - $\text{PaO}_2$ ? mmHg
  - $\text{SaO}_2$ 100%
  - $[\text{HCO}_3^-]$ 19 mEq/L
  - Base excess $-1.0$ mEq/L
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- Dr. made the following adjustments to the ventilator
  
  - Kept TV at 650 ml
  - Dropped rate from 30 to 20
  - Decreased FiO₂ from 100 to 50
  - Order another round of ABG’s

- ABG’s #4
  
  - pH 7.17
  - PaCO₂ 54 mmHg
  - PaO₂ 66 mmHg
  - SaO₂ 91%
  - [HCO₃⁻] 19 mEq/L
  - Base excess −10 mEq/L
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- Condition deteriorating
  - Metabolic acidosis
  - Blood pressure low and dropping, 80/60
  - Nurse informed the doctor that Mrs. S’s face was puffy
- Mrs. S heard this and informed the staff that she was taking prednisone
- Determined that the puffyness was not the result of prednisone rather it started after being placed on the ventilator, indication was subcutaneous emphysema
- Surgeon was called, and believed the problem was Mrs. S had a pneumothorax that must be resolved surgically with the placement of a chest tube
- This proved successful – five years later Mrs. S is fine, she takes bronchodilators and prednisone, along with erythromycin at the earliest sign of a respiratory tract infection
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• Case Discussion

  – Why was she retaining carbon dioxide during manual ventilation?

    • She was unable to lower intrathoracic pressure enough to get air through constricted passageways

  – Why not give sodium bicarbonate for respiratory acidosis?

    • Generate increased carbon dioxide
      
      – Would enter cells and lower intracellular pH

      – Affect cardiac muscle contraction, decreasing CO and increasing anaerobic respiration, generating more lactic acid
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- What was Mrs. S’s alveolar-arterial oxygen gradient during manual ventilation? – use the Alveolar Gas Equation

  • \((A-a)PO_2 = 203 - 161\)
  
  • \(= 42\)

  • Normal for a person breathing pure oxygen is < 30 (she was receiving about 50% at this time), the value of 42 is nearly normal indicating that the respiratory membranes are functioning normally

- Was supplemental oxygen really needed? What possible adverse reactions could have been expected had the portable oxygen tank run out of oxygen before reaching the ICU?

  • With a decrease in oxygen from 50% to 21% her PAO_2 would have dropped to 0 and she would have died
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- Why bother inserting an endotracheal tube?
  
  - To avoid air leaks that result when forcing air in at high pressures

- What was Mrs. S’s alveolar-arterial oxygen gradient after intubation?
  
  - $\text{PAO}_2 = 655$
  
  - $(A-a) \text{PO}_2 = 590$
  
  - An increase from 42 to 590
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- Why change the ventilator settings in response to ABG #3?
  - pH 7.5
  - PaCO₂ 24 mmHg
  - PaO₂ ? mmHg
  - SaO₂ 100%
  - [HCO₃⁻] 19 mEq/L
  - Base excess –1.0 mEq/L
  - Kept TV at 650 ml
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- Dropped rate from 30 to 20

- Decreased FiO₂ from 100 to 50

- A SO₂ in low 90’2 with a PaO₂ between 60 an 70 with a FiO₂ as low as possible is desirable

- Too great a use of high oxygen levels can be harmful if used for more than 24 hrs.
  - Adversely affect ciliary function
  - Interfere with surfactant secretion
  - If inspired air contains little or no nitrogen, when gas moves into the blood little or none remains in the alveoli and they tend to collapse
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- Why was Mrs. S given Proventil, aminophylline, hydrocortisone and erythromycin?

  • Proventil (albuterol) – beta$_2$-andrenergic agonist
    - Bronchodilation, by acting on smooth muscle cells, by increasing levels of cAMP
    - Prevents bronchoconstriction by inhibiting release of histamine and other mediators from mast cells

  • Aminophylline (theophylline) – acts like caffeine
    - Increases levels of cAMP
    - Stimulates CNS, respiratory drive
    - Improves cardiac function
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• Hydrocortisone (cortisol)
  – Inhibits synthesis of proteins (mediators of bronchoconstriciton such as histamine)
  – What are some of the problems with its use?

• Erythromyocin
  – Inhibits bacterial infections, which can precipitate an intrinsic asthma attack
  – In fact in Mrs. S her WBC was 28,600/cc
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- Why did Mrs. S have subcutaneous emphysema (gas bubbles under the skin)? How did it resolve? How could one speed its resolution?
  
  - What could cause this/
    
    - A ruptured bulla or blep on the surface of the lung
    
    - A puncture caused by a broken rib the result of too aggressive CPR

- Resolution
  
  - Oxygen would rapidly be absorbed by surrounding blood vessels
  
  - Nitrogen would remain for a longer period of time

- Speeding of Resolution
  
  - Administering pure oxygen, this would displace the nitrogen and cause a more rapid absorption of the gas under the skin
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- Why did Mrs. S’s blood pressure and pH fall when her face got puffy, and what would be the correct response?
  
  - As a consequence of a Tension Pneumothorax
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- Diffusion Barriers for Oxygen in the Lung
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A—NORMAL ALVEOLUS

B—PNEUMONIA

C—CONGESTIVE HEART FAILURE

D—INTERSTITIAL FIBROSIS
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- **Oxygen Transport from Lungs to Tissues**
  - 1.5% dissolved in plasma
  - 98.5% carried with Hb inside of RBC’s as oxyhemoglobin
    - Association of Hb with oxygen is affected by five factors
      - $pO_2$ – the greater the $pO_2$ the more oxygen will combine with Hb, until the Hb becomes saturated
      - $pCO_2$ – the lower the partial pressure of carbon dioxide greater the affinity of the Hb molecule for oxygen
      - Acidity pH – in a lower (more acidic) pH oxygen will dissociate from Hb and be released (frequently related to high carbon dioxide)
      - Temperature – as temperature increases, so does the the amount of oxygen released from Hb
      - BPG (2,3 biphosphoglycerate) – a chemical formed inside RBC’s during glycolysis – the higher the levels of BPG the more oxygen is released by Hb
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[Graph showing the relationship between PaO₂ (mmHg) and SaO₂ (%) with various factors like pH, PaCO₂, 2,3-DPG, and temperature affecting the curves.]
• Carbon Dioxide Transport from Lungs to Tissues
  
  – 5% dissolved in plasma
  
  – 30% carried by Hb as carbaminohemoglobin and other proteins in the blood (carbamino compounds)
  
  – 65% converted to bicarbonate (HCO⁻) ions