A Case of Respiratory Distress

by
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A 68-year-old, non-smoking female presented to the Emergency Room for evaluation of dyspnea (shortness of breath) of 1-hour duration. On examination, her vital signs were: temperature of 98.8°F; pulse of 90 beats/minute; respiratory rate of 20 breaths/minute; and weight of 140 lbs. In addition, lung sounds were clear (without wheezes or dullness). She indicated that she had been feeling unwell for over three days and that several of her family members had been coughing. She also indicated that she had self medicated on Bactrim™, a sulfonamide antibiotic that her much younger sister had been prescribed.

Initial arterial blood gas analysis indicated a pH of 7.50; P_{O2} of 96 mm Hg; P_{CO2} of 25 mm Hg; bicarbonate level of 24mmol/L; and oxygen saturation (SpO_2) of 88%. The patient's labored breathing subsequently worsened. The patient's pulse oximetry (SpO_2) reading worsened to 86% and did not increase after the patient was given oxygen by nasal cannula. A pulse oximetry reading measures oxygen levels in oxygenated blood; a healthy person normally has a value of 98–100%.

Blood drawn from the patient's left arm (from a vein) was chocolate colored. In a healthy individual, such blood is dark red. A second blood sample was drawn from the radial artery. Blood gas analysis revealed a methemoglobin level of 23%, a level that is way above the normal (of about 1%). This is consistent with the original findings and the lack of response to oxygen therapy.

Oxygen therapy was continued and methylene blue (1 mg/kg) was co-administered. Pulse oximetry readings indicated that SpO_2 improved to approximately 89%. Approximately 5 minutes after the first dose, another 1 mg/k dose of methylene blue was given and the SpO_2 improved to 92%. The patient was moved to the ward and, after two uneventful days, was discharged. She was provided with an inhaler containing a bronchodilator and instructed in its use. She was asked to use it in case of onset of renewed shortness of breath. She was cautioned to stop taking additional Bactrim™ and any prescription medication not specifically prescribed for her. She was also asked to follow up with her private physician.

Pre-Case Questions

To be done individually as an assignment prior to undertaking the case study in class.

1. Explain Le-Chatelier's principle.
   References:
   http://en.wikipedia.org/wiki/Le_Chatelier's_Principle
   http://www.chemguide.co.uk/physical/equilibria/lechatelier.html
2. Explain what is meant by pH.
   References:
   http://www.youtube.com/watch?v=pvB6XEGSY7A
   http://www.gpb.org/gpbclassroom/chemistry/1102

3. Explain the difference between an acidic, a basic, and a neutral solution. Why can water be acidic, neutral, or basic?
   Reference:
   http://en.wikipedia.org/wiki/Self-ionization_of_water
4. What is the pH range of blood in a healthy individual?
   Reference:
   http://es.youtube.com/watch?v=IBJtQtzN7O8
5. Explain a "buffer solution" and the principles underlying its action.
   Reference:
   http://en.wikipedia.org/wiki/Buffer_solution
6. Explain the principles underlying the buffering system of the blood.
   References:
   http://academic.brooklyn.cuny.edu/biology/bio4fv/page/bicarbo.htm
   http://scifun.chem.wisc.edu/CHEMWEEK/BioBuff/BioBuffers.html
   http://www.youtube.com/watch?v=WXOBJEXxNEo&feature=related
7. Explain the difference between respiratory acidosis, metabolic acidosis, respiratory alkalosis, and metabolic alkalosis.
   Reference:
   http://scifun.chem.wisc.edu/CHEMWEEK/BioBuff/BioBuffers.html
8. Blood contains the protein hemoglobin, which is capable of binding to oxygen molecules and transporting to cells where they are released. The reaction between Hb and O_2 can be represented by the following equation:

   $$Hb + O_2 \rightleftharpoons HbO_2$$

   (a) In the lung (where there is a high concentration of O_2), which direction is the equilibrium favored?
   (b) In the tissues (where there is a low concentration of O_2), which direction is the equilibrium favored?
   (c) In which direction will the equilibrium shift if there is a lower than normal level of hemoglobin in the blood? What consequence will this have on a person's ability to transport sufficient oxygen to the tissues?
   (d) How would the body likely compensate for a decreased level of hemoglobin?
   (e) The blood also transports CO_2 from the tissues to the lung where it is expelled during breathing. What will likely happen to the levels of blood CO_2 if a person were to breathe faster and deeper?

   Reference:
   http://www.merck.com/mmhe/sec04/ch038/ch038d.html
9. What are some of the conditions that can lead to lower than normal levels of hemoglobin?
   References:
   http://www.mayoclinic.com/health/low-hemoglobin/AN01295 http://www.emedicine.com/med/topic3002.htm
10. Explain the relative roles that Fe^{2+} and Fe^{3+} play in the structure and function of hemoglobin.
    Reference:
    http://en.wikipedia.org/wiki/Hemoglobin
11. What is methemoglobinemia? How can it be acquired and how is it manifested? (Do not summarize or give too many details from the reference article. Write a simple and very short one-paragraph response.)
    References:
    http://www.emedicine.com/med/TOPIC1466.HTM
    http://en.wikipedia.org/wiki/Methemoglobinemia
12. Very briefly explain what is Bactrim™, how it works, what is it used for, and some of its contra-indications.
    References:
    http://en.wikipedia.org/wiki/Bactrim

http://www.drugs.com/bactrim.html
http://www.webmd.com/drugs/drug-5530-Bactrim+DS+Oral.aspx?drugid=5530&drugname=Bactrim+DS+Oral

Case Questions

Note: While you will work on these in your groups, each student is also responsible for submitting an individual write-up of answers to these questions after class.

1. There is a likelihood that the patient has acquired pneumonia since she exhibited shortness of breath and has been in contact with family members who had been coughing and were treated for pneumonia. In addition, her age makes her more susceptible to respiratory infections such as pneumonia. The latter is characterized by fever (a body temperature above 37.2 ºC), coughing, decreased breath sounds, and hyperventilation. Does the patient have pneumonia? Justify your answer.
2. How does the patient's blood pH, P_{O2}, P_{CO2}, oxygen saturation levels, and bicarbonate levels compare with those of a healthy individual?

   Reference:
   http://www.nlm.nih.gov/medlineplus/ency/article/003855.htm
3. Referring to question 7 from your homework, what conclusions can you draw from the results of the patient's arterial blood gas analysis? Justify your answer.
4. What was the diagnosis for the patient and what likely caused the condition?
5. Initial arterial blood gas analysis indicated that the patient had a pH of 7.50. By how much is the $[H_3O^+]$ in deficit?
6. If the patient has a blood volume of 4.7 L, how much H^+ is in deficit?
7. Why did the patient not respond to oxygen therapy initially?

$$Hb + O_2 \rightleftharpoons HbO_2$$

8. The patient had a blood P_{O2} of 93 mm Hg and P_{CO2} of 25 mm Hg. What are the molar ratios of O_2 and CO_2 in the patient's blood?
9. The patient was treated with a total of 2 mg/kg of methylene blue. If the patient weighs 140 lbs, how much methylene blue was she treated with?
10. Methylene blue is usually administered intravenously as 1% (m/v) solution. What volume of methylene blue containing IV solution was administered?
11. The intravenous administration of methylene blue was followed by a saline flush. What is the reason for the flush?
12. Explain the principles underlying the mode of action of methylene blue.

    Reference:
    http://www.emedicine.com/med/TOPIC1466.HTM
13. Why did the patient become responsive to oxygen after the methylene blue treatments?
14. If the patient is a relative of yours, what advice would you give to her (after she is discharged)?