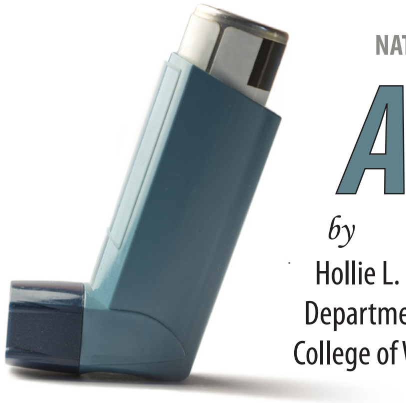
NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE



Asthma Attack!

by
Hollie L. Leavitt
Department of Biology
College of Western Idaho, Nampa, ID

Part I – Background Information

Jaden Hunter, 11 years old, stumbled into his parents' bedroom. It was 4 a.m. and completely dark. Unable to talk, he simply grabbed his mother's foot to get her attention. His mom awoke immediately and shouted "Brandon, get up!" Without explanation, she knew what the problem was. She helped Jaden onto the bed next to her husband, then raced down the stairs and grabbed the backpack full of medical equipment they used when things got this bad.

When she returned Jaden was sitting on the bed being comforted by his father. While slipping a mask over his face to deliver nebulized albuterol, his mother recalled the events earlier in the day. Jaden had enjoyed a field trip with his STEM club where they attended the local race track to learn about the engineering of race cars. At one point during the event, one of the drivers offered to start up the car for the group of excited school kids. He warned "Before I do this, if you have asthma you'll want to step way back." A happy and excited Jaden didn't want to leave, but his mom recognized the danger and led him away from the car. Just a few moments later the driver revved the engine. The deafening sound was followed by a plume of green smoke—nitromethane exhaust. Jaden immediately needed his quick-relief rescue inhaler, and his mother took him home.

Asthma is a condition caused by chronic inflammation of the small airways in the lungs. This leads to swelling and increased mucus production within conducting zone passageways. Due to the chronic inflammation, an asthmatic's airways are already more narrow than the airways of an individual without this disease (Figure 1). Situations that may cause the airways to constrict or spasm are common. Exposure to dry and/or cold air, contact with pollen or other allergens, illnesses such as a cold or the flu, certain medications and foods, or even just stress can cause this bronchoconstriction to occur (AAAAI, *n.d.*). This usually does not cause a problem for a non-asthmatic, but for someone with asthma, bronchoconstriction can severely decrease the diameter of the already swollen, mucus-producing airways, making it very difficult to move air into and out of the lungs. The decrease in air flow can range from mild to life-threatening, and may cause a great deal of anxiety for someone actively suffering from an acute asthma exacerbation, or asthma attack.

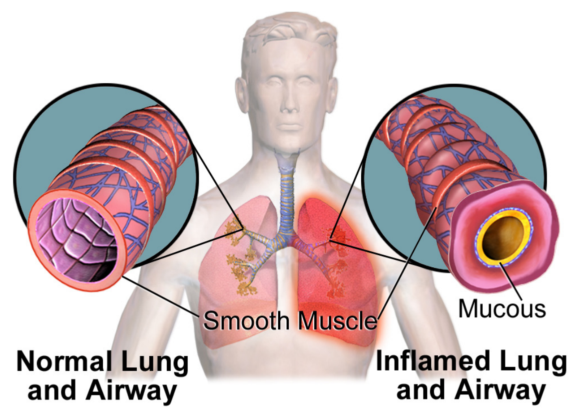


Figure 1. The respiratory passageways in a non-asthmatic (L) and asthmatic (R) lung. *Credit:* BruceBlaus, CC BY 3.0.

Questions

You may need to use the internet or another source to help answer some of the questions in this case study.

1. According to the passage above, what are the three factors involving the airways that lead to an asthma attack?
2. What is contained within a quick-relief rescue inhaler?
3. How did the quick-relief rescue inhaler help Jaden to breathe easier at the race track?
4. What is nebulized albuterol, and how does it help with an asthma exacerbation?

Part II – The Oxygen-Hemoglobin Dissociation Curve

Following his nebulizer treatment, Jaden was breathing a little better and able to talk.

"I used my rescue inhaler all night . . . it didn't help!" He paused for a breath and then said, "We used my nebulizer . . . right before bed . . . I still couldn't sleep . . . My chest feels tight."

"Do you feel like we need to go to the hospital?" his mom gently asked. Jaden looked down and simply nodded his head yes. Having suffered from asthma since the age of four, he understood that his symptoms had reached a point where they couldn't be adequately managed at home.

Luckily, the hospital was just a short drive away. Brandon stayed home with Jaden's little sister, Chloe, and Jaden and his mom headed to the car. It wasn't the first time they had made this trip in the middle of the night. In fact, it seemed like every time Jaden had breathing problems severe enough to warrant an emergency room trip it was in the middle of the night.

As they arrived at the hospital Jaden's chest tightness was once again beginning to increase and he was unable to take deep breaths. The panic this caused him lead to tears, which only made his breathing problems worse. His mom knew that the best thing she could do to help him was to stay calm herself and gently guide him through breathing exercises, so she set aside her own fears and panic, and started to do just that as she checked him into the ER.

Once back in the examining room a pulse oximeter was immediately placed on Jaden's finger and vital signs monitored. Jaden's oxygen saturation (So_2), or the percentage of his hemoglobin binding sites bound to oxygen, was 82%.

Use Figure 2 of the oxygen-hemoglobin dissociation curve to answer the questions below.

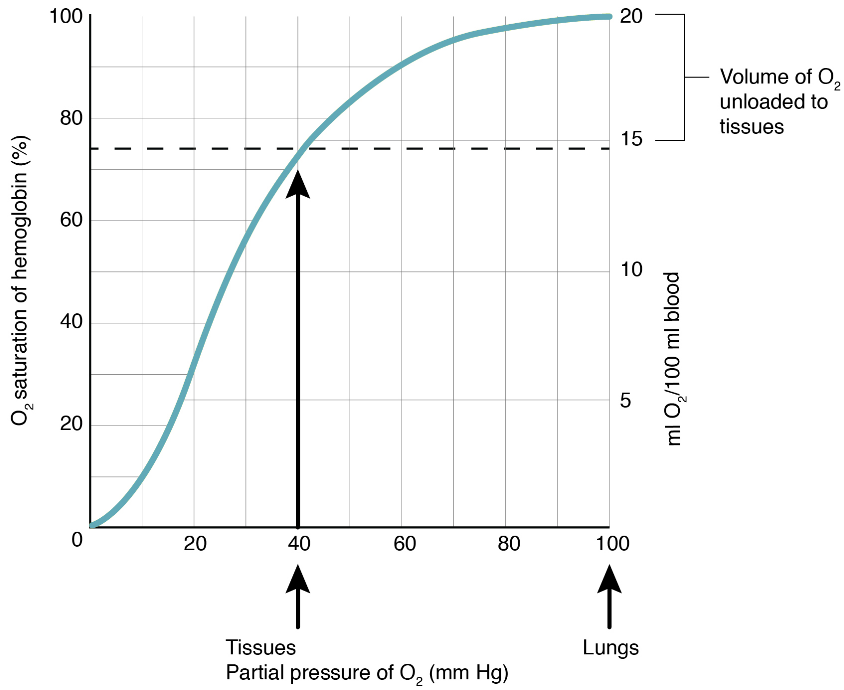


Figure 2. The oxygen-hemoglobin dissociation curve. *Credit:* OpenStax College, CC BY 3.0.

Questions

1. Based on his So_2, what is the partial pressure of oxygen (Po_2) dissolved in Jaden's blood plasma?

2. How does Jaden's Po_2 compare to the normal, expected Po_2 for arterial blood?

3. Provide a reason for the change from normal arterial Po_2, and explain how this change affects oxygen delivery to Jaden's tissues.

Part III – The Effects of Air Flow on Po_2 and Pco_2

Because asthma is an obstructive respiratory disease caused by a decreased diameter in the respiratory passageways, Jaden was having problems both with breathing in and with breathing out. Air flow through the respiratory passageways can be calculated by using the following formula:

$$F = \Delta P / R$$

Where:

F = air flow

ΔP = the difference between atmospheric and intrapulmonary pressure

R = resistance

Questions

1. How does the body create a difference between atmospheric and intrapulmonary pressures to cause air flow to and from the lungs?

2. In Jaden's case, which factor in the above equation changed, causing air flow to and from his lungs to decrease?

3. Without medication or treatment, how could Jaden compensate to maintain airflow to and from his lungs despite his narrowed airways? In your answer, be sure to reference the formula for air flow given above.

4. Explain why asthma exacerbations and other obstructive lung diseases that make it difficult for air to move into and out of the lungs can be exhausting for the sufferer. (*Note:* this goes beyond the fact that the sufferer is oxygen deficient and that often the problem happens at night. You need to discuss the mechanical strain that this places on the body due to the requirements to maintain airflow to and from the lungs.)

5. The Pco_2 of venous blood is normally 45 mmHg. How would you expect Jaden's current Pco_2 level to compare to the normal level? Explain your answer.

6. How would Jaden's Pco_2 level affect the rate at which his oxygen is dissociating from hemoglobin? (Remember the Bohr effect.)

Part IV – Spirometry

Spirometry is a test that is done as part of a normal, routine check-up for an asthmatic. In addition, it is also often performed during asthma exacerbations to assess lung function. During the test a patient is required to breathe through a tube that measures air flow into and out of their lungs. Usually the patient is asked to breathe in and out normally, before being required to breathe in as deeply as possible and then breathe out as deeply and quickly as possible.

Familiarize yourself with Figure 3 and then answer the questions below.

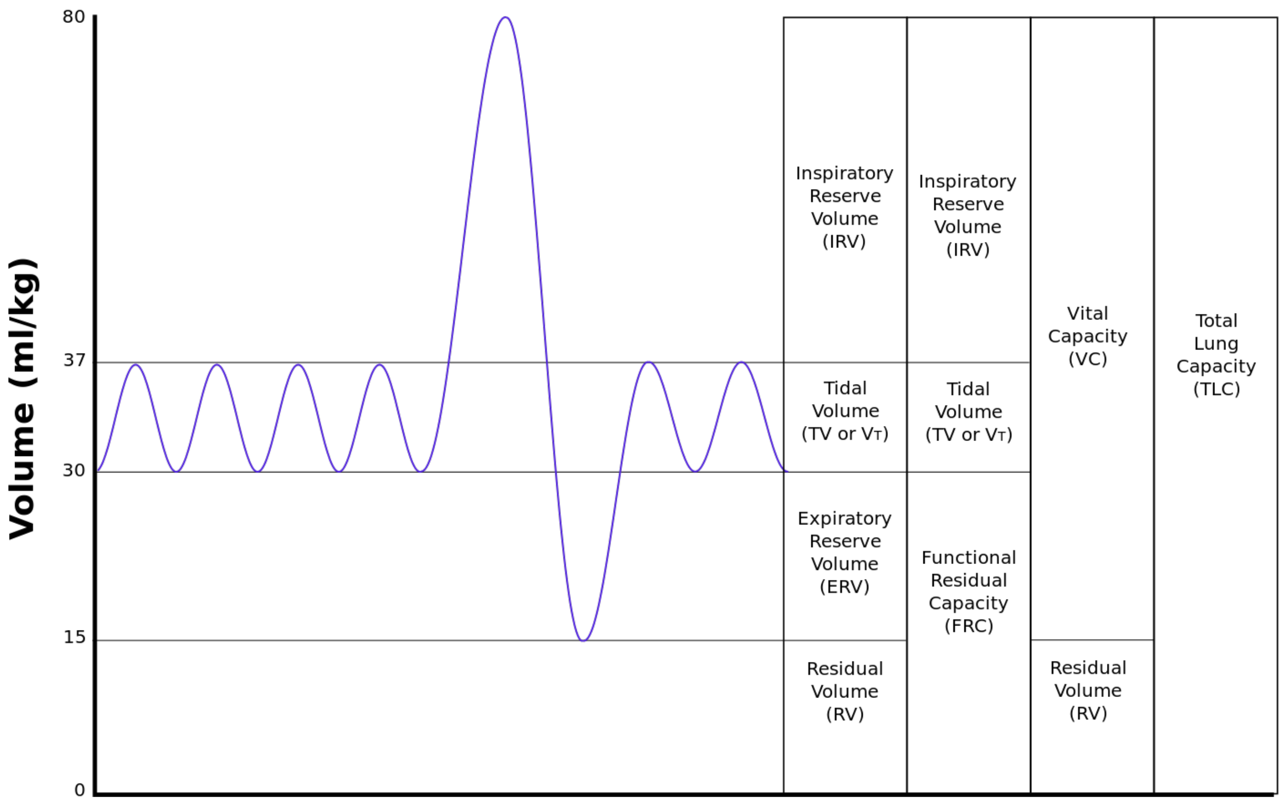


Figure 3. Respiratory volumes. *Credit:* LungVolume.jpg, CC BY-SA 3.0, <https://commons.wikimedia.org/wiki/File:Lungvolumes.svg>.

Questions

1. Provide definitions for the following: *tidal volume, inspiratory reserve volume,* and *expiratory reserve volume.*

2. How do you think that each of these lung volumes (tidal, inspiratory reserve, and expiratory reserve) would change for someone experiencing an asthma attack?

3. Explain why spirometry (the measuring of these lung volumes) can be used to get an idea of basic lung function and determine whether or not someone is currently suffering from asthma or another respiratory disorder.

Part V – Treatment

Jaden's asthma specialist, Dr. Palmer, was on call at the hospital and popped into the ER to see how Jaden was doing. Jaden had been placed on a continuous nebulizer, given 20 mg of prednisone, and was continuing to have his vitals monitored. His So_2 had increased to 95% and had remained there for approximately an hour.

"Well, it looks like we've had some improvement," the doctor said. "Blood oxygen levels have been above 90% for a while now. Let's discontinue the nebulizer. If we can keep his So_2 above 90% without it, then we'll let you guys out of here soon."

It was now 7 a.m. and Jaden was dozing on the table. Dr. Palmer put his hand on Jaden's shoulder to gently wake him and said, "It seems like the last time I saw you we put you on a long-term asthma preventative—Advair was it? Have you been taking your Advair twice a day like we talked about?"

"Well, I take it sometimes. But I forgot to take it for a while because I couldn't find the inhaler."

"Jaden, if you don't want to come to the hospital in the middle of the night, or at any other time for that matter, you've got to take your Advair like we talked about. We're going to keep you on prednisone for the next five days. Please take 20 mg twice a day and continue to use your nebulizer every 4–6 hours until you feel like you are breathing better and your chest is no longer tight."

An hour later Jaden and his mom headed home after a very long night.

Questions

1. Use the oxygen-hemoglobin dissociation curve (Figure 2 in Part II) to determine what Jaden's Po_2 is if So_2 is 95%.
2. Why is Dr. Palmer concerned that Jaden's So_2 stay above 90%?
3. How do long-term asthma control medications such as Advair work to prevent asthma attacks?
4. How did prednisone help to reverse Jaden's symptoms?

Internet Resources

AAAAI (American Academy of Allergy, Asthma and Immunology). *n.d.* Asthma triggers and management. <https://www.aaaai.org/conditions-and-treatments/library/asthma-library/asthma-triggers-and-management>.

Mayo Clinic. *n.d.* Hypoxemia. <http://www.mayoclinic.org/symptoms/hypoxemia/basics/definition/sym-20050930>.

Bottrell, J. 2015. Understanding oxygen and oxygen levels with COPD. <http://www.healthcentral.com/asthma/c/52325/175572/understanding-oxygen-levels/>.

National Center for Biotechnology Information. PubChem Compound Database. Prednisone, *CID=5865.* <https://pubchem.ncbi.nlm.nih.gov/compound/5865>.