

The Heart of the Problem: From Heart Attack to Kidney Failure

by

Kristine A. Garner and Brandy C. Ree

Department of Biological Sciences

University of Arkansas – Fort Smith

Part I – Emergency

Mrs. Helms came in through the front door of her house with an armful of groceries. She put the bag down on the kitchen counter and called to her husband. “Herb, I’m home! Are you ready for lunch?” She didn’t get an answer, so she walked to the living room and found Mr. Helms lying on the floor. “Herb! Are you okay?” she asked as she grabbed his shoulder. Mr. Helms responded weakly while clutching his chest. Mrs. Helms frantically called 911. It only took EMS a few minutes to arrive and the paramedics transported Mr. Helms to the hospital. Upon admission to the hospital, Mr. Helms’ vital signs were recorded as follows:

	<i>Mr. Helms</i>	<i>Normal</i>
Systolic blood pressure (mm Hg)	90	120
Diastolic blood pressure (mm Hg)	52	80
Oral temperature (°F)	98.9	97.8 to 99.1
Heart rate (beats per minute)	120, irregular	60–80
Respiratory rate (breaths per minute)	33, labored	12 to 20
Oxygen saturation	89%	95–100%

Questions

1. Which of Mr. Helms’ vital signs and lab values were abnormal?

- Low systolic and diastolic blood pressure (overall, blood pressure is too low — about 30mm Hg too low for both systolic and diastolic)
- Heart rate is too high as compared to normal
- Respiratory rate is too high as compared to normal
- Oxygen saturation is a bit low
- He was having trouble breathing and his heart was not beating properly

2. What additional medical tests would you order for Mr. Helms? In other words, what other information would be useful?

- ECG
- Echocardiogram
- Chest X-ray
- Blood gases
- Blood pH

Part II – Cardiac Involvement

Mr. Helms was admitted to the hospital with chest pains and shortness of breath. His wife was panicked since her 72 year-old husband had a history of heart disease. After examination and an echocardiogram, Dr. Collins spoke with Mrs. Helms. “I’m very sorry, but your husband has had another heart attack resulting in valve failure. A papillary muscle that controls a valve in his heart has been severely damaged and is no longer working.”

Questions

1. What is the purpose of blood flow?

- Blood flows through the body to deliver oxygen and nutrients to cells and to transport waste products and toxin to organs of secretion

2. Describe blood flow through the heart starting with blood entering the right side of the heart and including all chambers and valves.

- blood enters the heart through the superior and inferior vena cava (veins) to enter the right atrium of the heart
- Blood passes through the tricuspid atrioventricular valve into the right ventricle
- Blood is then pumped out of the pulmonary semilunar valve out into the pulmonary artery where deoxygenated blood is oxygenated at the capillaries of the lungs. This is achieved through the contraction of the right ventricle
- Oxygenated blood enters the left atrium of the heart through the pulmonary veins and then enters the left ventricle of the heart by passing through the bicuspid atrioventricular valve (the mitral valve).
- Oxygenated blood is pumped through the aortic semilunar valve and into the aorta (an artery). From the aorta, blood vessels diverge and carry this oxygenated blood to the entire body. This is achieved by the contraction of the left ventricle

3. What is the function of heart valves?

- Heart valves prevent the backward flow of blood. They allow the ventricles to fill with a large volume of blood before pumping it throughout the body at a high level of efficiency

4. What is the function of papillary muscles?

- Pressure builds from blood pushing against the atrioventricular (AV) valves during ventricular contraction (systole)
- Papillary muscles contract during ventricular systole to keep the valves closed during ventricular contraction (preventing prolapse of the valves into the atria)

5. Which valve is affected with damage to the papillary muscle in the left ventricle?

- The bicuspid (mitral) valve would be effected by damage to the papillary muscle in the left ventricle

Part III – Cardiovascular Involvement

Dr. Collins called Nurse Nan from the patient's room and confided, "Mr. Helms is in bad shape. His left posteromedial papillary muscle was damaged from his heart attack. The papillary muscle is no longer able to maintain closure of the valve, and this has resulted in mitral valve prolapse. With decreasing cardiac output, this patient is in for a fight for his life." Nurse Nan knew that maintaining cardiac output was necessary for adequate blood flow through the body. As Dr. Collins walked away, Nurse Nan composed herself to tell Mrs. Helms the bad news and returned to the patient's room. Nurse Nan explained to Mrs. Helms that her husband had left-sided heart failure and that his blood pressure was slowly and steadily decreasing.

Questions

1. In general, how is the direction of blood flow disrupted because of mitral valve prolapse?
 - If the mitral valve is not closing completely, then blood flow will be reduced from the left ventricle into systemic circulation while blood flow will increase from the left ventricle back into the left atrium.

2. Does the mitral valve prolapse increase, decrease, or not change stroke volume (the amount of blood exiting the ventricle with each ventricular contraction)?
 - because some of the blood is backing up into the atria, less blood is being pumped out of the heart, which decreases stroke volume

3. How does mitral valve prolapse decrease cardiac output (the amount of blood exiting the ventricle per minute)?
 - cardiac output is the product of stroke volume and heart rate. Because stroke volume decreases, less blood is being pumped out of the heart per beat, which decreases cardiac output

4. Explain how cardiac output determines blood pressure.
 - blood pressure is based in part on the amount of blood pumped out of the heart per minute.
 - If there are no other physiological changes, blood pressure increases if a greater volume of blood is pumped into the blood vessel than the amount of blood that leaves.

5. Why is Mr. Helms' heart rate higher than normal?
 - Heart rate increases to compensate for low blood pressure, which is the result of low cardiac output

Part IV – Pulmonary Involvement

Mrs. Helms was very upset with the news of her husband's condition. As the day progressed, she noticed that Mr. Helm's breathing was increasingly difficult. He could barely speak without losing his breath. Mrs. Helms called the nurse to her husband's room. "My husband can't breathe! What is wrong? I thought he had a heart attack not a respiratory condition!" Nurse Nan auscultated the patient's chest listening to Mr. Helms' respirations, which were rapid and wet, producing rales or crackling sounds. Nurse Nan calmly informed Mrs. Helms, "I'm sorry. Your husband's condition is worsening. The damage to his heart is causing his respiratory problems."

Questions

1. The left side of the heart receives blood from which part of the body?

The lungs (blood enters the left side of the heart through the pulmonary vein) oxygenate the blood which enters the left side of the heart (the left atrium)

2. If the bicuspid (mitral) valve is not fully closing, does pulmonary circulation increase, decrease, or not change?

If the mitral valve is not fully closing, pulmonary circulation will decrease.

3. Does pulmonary blood pressure increase or decrease with left-sided heart failure? Explain.

4. Does this change in pulmonary blood pressure increase or decrease capillary filtration in the lungs? Explain.

5. How does change in pulmonary blood pressure and capillary filtration cause Mr. Helms' rales (wet breath sounds)?

6. Why is Mr. Helms breathing rapidly?

Part V – Renal Involvement

The next morning when Nurse Nan started her shift, she immediately checked on Mr. Helms. His cardiovascular and respiratory conditions were still deteriorating, but Nurse Nan discovered something new. Mr. Helms' urine output was almost nonexistent. Nurse Nan informed Dr. Collins, who was gravely concerned. Dr. Collins met with Mrs. Helms to tell her that her husband could not survive kidney failure. Mrs. Helms looked shocked. She then became very upset and angry. "What did you do, Dr. Collins? My husband had a heart attack, but his kidneys were fine; he's never had a kidney problem! How could you let this happen?" Nurse Nan put her arm around Mrs. Helms' shoulders and Dr. Collins handed her a tissue. Dr. Collins explained, "The damage to your husband's heart is very serious. The kidneys rely on blood pressure to work and his heart failure is causing the kidney failure."

Questions

1. What are the functions of the kidneys?

2. What is the force that causes the filtration of the blood by capillaries in the kidneys to occur?

3. Does left-sided heart failure increase, decrease, or not affect kidney filtration? Explain.

Part VI – Resolution

Dr. Collins rushed Mr. Helms into surgery for valve replacement. Mrs. Helms waited anxiously in the waiting area for family for hours until she saw Nurse Nan coming toward her with a big smile. “Your husband is in the recovery room. He’s going to be just fine.” Mrs. Helms sighed with relief and gave Nurse Nan a big hug.

Questions

1. How would you expect Mr. Helms’ vital signs and respiratory and kidney functions to change after valve replacement surgery? Explain.

2. Now that you are familiar with left-sided heart failure, describe blood flow with right-sided heart failure.

3. What are some possible causes of right-sided heart failure?

4. What symptoms could be expected with right-sided heart failure?



Case copyright held by the **National Center for Case Study Teaching in Science**, University at Buffalo, State University of New York. Originally published December 8, 2015. Please see our **usage guidelines**, which outline our policy concerning permissible reproduction of this work. Licensed photo in title block © Win Nondakowit | Fotolia, ID 67898135.

POP QUIZ — These questions could show up on a midterm/final (According to our TA):

NOTE: **RED** = Incorrect Option — **GREEN** = Correct Option

Question 1

Which of these statements describes why the heart valves open and close?

There is prolonged calcium influx

There is turbulent flow in the atria and ventricles

Na⁺ and K⁺ fluxes occur during ventricular depolarization

There is a pressure difference on the two sides of the valve

Question 2

Which of the following describes the first heart sound?

It occurs when the semilunar valves close

It signals the end of ventricular systole

It signals the onset of ventricular systole

It occurs when the AV valves open

Question 3

Which of these events happens in an insufficient AV valve

The AV valve fails to open completely

THE AV valve produces a gurgling diastolic murmur

The AV valve produces a gurgling systolic murmur

The AV valve fails to close completely

Question 4

Stroke volume is equal to which of the following?

The product of heart rate and EDV

Difference between stroke volume at rest and stroke volume during exercise

Stroke volume minus end systolic volume

The difference between end-diastolic volume and end systolic volume

Question 5

If the stroke volume is 80mL and the heart rate is 70 beats per minute, what is the cardiac output?

150mL/min

560mL/min

8700mL/min

5600 mL/min