Anyone Who Had a Heart: A Case Study in Physiology

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Part I—Prenatal Visit

It had been a hectic day for the doctor, and his last patient was on time for her appointment.

"Hi. Sis."

"Hi, Jim. How's my kid brother?"

"Tired—how's the first-time mom? Have you stopped work yet?"

"Come on, Jim, I'm a career woman. The chemical industry needs me. It's tough to go cold turkey. When Dave and I decided to have a family, we agreed that I should work as long as I could."

"You're the size of a house, Jen. You're 37 years old, you have twins that are 28 weeks, and I really would like you to carry them as long as you can."

"Oh, oh, here comes the lecture again. I know you didn't like the fertility procedure we did, but I just couldn't get pregnant. Anyway, as you so tactfully pointed out, doctor, I am not getting any younger. Look at it this way; we're having our family all at once."

There was a knock at the door and the nurse entered.

"How did the ultrasound go?"

"It's like Times Square," replied the nurse. "Arms and legs everywhere—it's almost impossible to see anything, and those kids are so active. I just hope they slow down after they're born, otherwise you'll get no rest until they go to college. It's crazy in there, with two hearts beating. And with yours in the background, it's tough to isolate one. As best as I can tell, the rates are around 130 to 160 beats a minute."

"OK, well let's see if the expert can hear anything."

Both women glared at the doctor.

"Do you need the crane or can you get up on the table by yourself?"

Jen looked at the nurse and said, "Is he like to this to all his patients?"

"No comment; I need this job."

They laughed and Jim went to work. Moving the head of his stethoscope to different locations, he tried to isolate the sounds from one heart. His expression changed as he listened intently. Jen began to worry as her brother took longer than usual with his stethoscope.

"Is everything OK?" she asked.

Jim looked concerned. He was reluctant to tell his sister that he thought he had heard a heart murmur. Like his nurse had said, it was difficult to hear just one heart. He didn't want to alarm his sister, so he made a joke of the situation.

"Must be a girl in there, she won't stop talking. I think she said something about not leaving the hospital in just any outfit."

Jen went to hit her brother, but he easily evaded the playful smack.

"It's tough to predict when the babies will arrive, so I think you should start coming to see me every week, Jen."

"Is there a problem? You did all of the tests, and you said that I'm not diabetic. The alpha-fetoprotein levels indicate no neural tube defects, and that horrible amniocentesis procedure showed no birth defects or Rhesus problems."

"It's OK, Sis. It's quite normal for women who are close to delivery to visit their OB-GYN every week. It's tough to predict delivery with multiple births, because they rarely go full term. So, to be on the safe side, let's get together every week from now on. In that way I can see your lovely smiling face more often."

Jen scowled at her brother.

"For once in your life, do what I ask," Jim said. "And bring Dave with you next time."

A little later, as Jim was finishing his paper work for the day, the nurse returned to his office.

"Everything OK with Jen?"

"I can't stop thinking about that vague sound I heard. It sounded like a heart murmur, but it's so tough to single out with two kids in there."

"I thought I heard it too. The babies seem active and are about the same size. No history of birth heart defects in either family, but I guess you never know with twins in an older mom."

"My thoughts exactly. I don't want to worry her because you know how hyper she can be. I guess we'll need to keep a close eye on her, and on my nephew and niece."

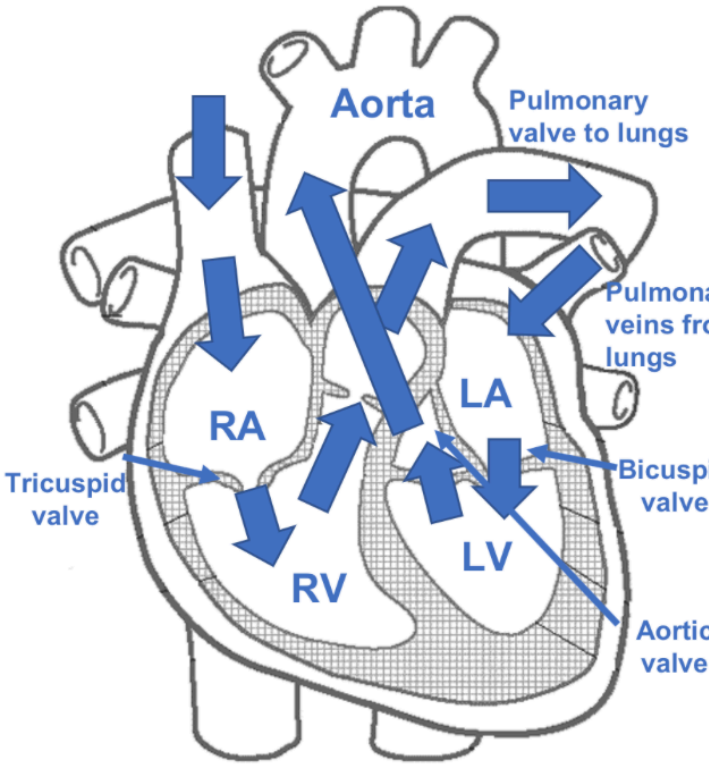
"Does Jen know the sexes?"

"She and Dave don't want to know. They want to be surprised."

Questions

1. Draw a diagram of the heart of a human adult. Show the circulation of the blood through the heart and to and from the body and the lungs.
2. Draw a diagram of the heart of a human fetus. Show the circulation of the blood through the heart and to and from the body and the lungs.
3. What are the major structural differences between the fetal and the adult human heart? Draw and label these differences on your diagram of the fetal heart. How do these structures alter the circulation of blood?
4. Why is the pulmonary circulation reduced in the human fetus?
5. Are heart rates of 130 to 160 normal in a human fetus?

1)



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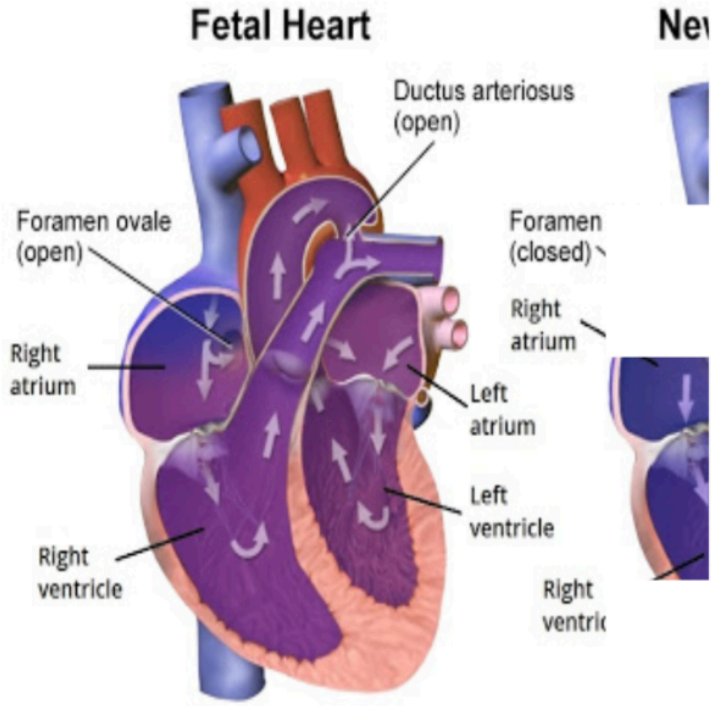

3)

- foramen ovale --> allows blood to flow from the right atrium to the left atrium
- ductus arteriosis --> allows blood to flow from the pulmonary artery to the aorta
- both provide a right-to-left shunt

4) The lungs are collapsed. A discussion of vessel diameter blood flow can be introduced at this stage.

5) yes they are

Part II—The Arrival

The ambulance that carried Jen sped through the crowded streets with its sirens blasting and lights flashing. The traffic parted, and people watched as the vehicle made its way to the hospital.

"My water had to break right in the middle of a meeting."

"Don't worry, Jen. I'm sure they understand."

Her husband, Dave, was trying to comfort her, but then, true to form, he said something wrong. "Anyway, it'll give them something to talk about around the coffee machine."

Jen thought how lucky she was that her husband worked in the same office, but she didn't like the idea of being the topic of office gossip. She was beginning to feel motion sickness from lying on a stretcher in a moving vehicle. Just then the ambulance stopped, its doors opened, and she was being wheeled down a long corridor.

Finally, the stretcher turned a corner and she felt Dave leave her side as she entered a delivery room. She felt the sting of a needle in her left hand. Then she felt Dave's hand slip into hers and saw his eyes like slits between the cap and the surgical mask he had put on.

Jen felt a needle go into her back and almost immediately the lower half of her body felt numb; the epidural had taken effect. She looked up into the mirror and saw the surgeon with a child in his hands. The noise of first one crying baby and then another filled the room.

Jen held the babies and everyone, except Dave and the nurse, left the room. The babies were passed between the two of them as the nurse performed various tests.

"I came as quickly as I could," Jim said as he entered the room like a hurricane.

Jen thought that he had been late for almost everything in his life, but she would forgive him this time. Jim kissed his sister, smiled at his brother-in-law, and then went over to the nurse. Jen and Dave could hear them talking softly.

"No problem, doctor."

Jim came over to the new parents. "So, one of each. Any names picked out?"

"Brianna and Christopher," said Jen.

"OK, Doc." Dave smiled because he knew that Jim hated being called Doc. "Why were they blue when they were born?"

"That's quite normal, but they should have changed to pink a minute or so after they were born."

"So why does Brianna still have blue finger tips and lips?" asked Jen.

"It's called cyanosis; it's not uncommon. Don't worry. One advantage of being related to a doctor is that all three of you will get first-class treatment."

"I hope so, because Chris has pink lips, and he's breathing at a much slower rate than his sister."

Questions

1. What vital signs or symptoms do the two babies exhibit?
2 What is cyanosis?

3. Would you be alarmed that Brianna has cyanosis and Christopher does not? Why?
4. Why would the cyanotic baby have a faster breathing rate?
5. What are the possible diagnoses for Brianna's condition at this time? For each diagnosis that you come up with, describe the signs or symptoms that relate to that diagnosis.

5 not covered in tutorial

1)

- Brianna is cyanotic, breathing faster
- Christopher appears normal (he may be considered as the 'control')

2) Cyanosis is a blue skin coloration produced by low oxygen levels in the tissues

3) Yes. She should have recovered within the same time frame as her brother.

4) Low oxygen and perhaps higher blood carbon dioxide levels, abnormal hemoglobin, abnormal function of the "great vessels" in the heart, chronic obstructive pulmonary disease, amniotic fluid still in the lungs.

Part III—The Babies

A wave of exhaustion washed over Jen as a second nurse entered the delivery room.

"OK, it's time for Mom to check into her room. The pediatric nurse will take the babies to the greenhouse where you can show them off to your family."

"Don't worry, they call it the greenhouse because of all of the windows where friends and relations can come and see the babies," explained Jim. "You will be here a few days because of your surgery, Jen, and you'll need to get some rest. Dave, why don't you go up with Jen and settle her in? I'll stay here with the nurse and make sure the kids don't get lost. I'll be up soon."

The new parents smiled and left the delivery room.

"Nice job, Doc."

At that moment, Dr. Penny Smothers entered the room with a fresh-faced medical student.

"No sense in worrying the new parents. Hi, Penny. I am afraid we may have problems with the new arrivals."

"Hi, Jim, nurse, this is Sam Jones. He's a medical student interested in becoming a pediatrician. He'll be following me around for the next few weeks. Now, the babies, were there any prenatal indications of problems?"

"I thought I heard a heart murmur, as I told you when Jen selected you to be the kids' doctor, but it was tough to get a clear handle with twins."

"OK, Sam, you're up. Go listen to each child's heart and tell us what you think. Please remember your bed-side manners. Their names are on the plastic ring around their ankle, so please remember how you upset the last set of parents with twins. Get into the habit of using their names rather than referring to them as that one!"

Sam listened to the heart of each child with a stethoscope.

"Christopher has a heart rate of about 120, his heart sounds normal, and his color is pink. Brianna is cyanotic. Her breathing is much faster and deeper than Christopher's, and she is beginning to cough. She has a heart rate of 160 and a heart murmur—and there is a whirring sound between the lub and the dub."

"Well, let's hope that's an exaggeration," Penny whispered to Jim as they went over to examine the children."

"Oh, my gosh, he's right!" Penny exclaimed. "Nurse, get Brianna into the neonatal intensive care, stat. If there's room, try to get Christopher in there too."

She turned to her student.

"OK, Mr. Hotshot, what tests do you think we should do?"

Even though the tension was high and Jim had a personal interest in the health of his newly arrived nephew and niece, he couldn't help but smile as Penny rewarded her student's good work with more pressure.

Questions

1. What additional signs or symptoms do the two babies exhibit?
2. What creates the lub heart sound?
3. What creates the dub heart sound?

4. What is a heart murmur?
5. Do murmurs have different sounds and are they correlated with different problems?
6. What creates the whirring sound between the lub and the dub in Brianna's heart?
7. What are the possible diagnoses for Brianna's condition at this time? For each diagnosis that you come up with, describe the signs or symptoms that relate to that diagnosis.
8. If you were the pediatrician, what tests would you perform to help you narrow the possible diagnoses for Brianna's condition?

1)
- Christopher: Heart rate of 120; heart sounds are normal; colour is pink.
- Brianna: Heart rate of 160; heart murmur (whirring between the lub and dub); breathing is fast and deep; coughing

2) The closing of the valves between the ventricles and the atria
3) The closing of the valves between the ventricles and the arteries
4) An anomalous heart sound, which is often due to one or more dysfunctional valves
5)
- A whistling sound is produced by a (stenotic) valve, which does not open completely
- A whirring sound is produced by a leaky (or incompetent) valve, which allows blood to flow in the wrong directi

6) Most students select a dysfunctional valve between the ventricles and the atria -- Usually a mitral valve infraction (on the left side, where the pressure is usually higher than on the right).
7) Mitral valve prolapse fits the data. If blood leaks from the contracting left ventricle to the left atrium, this would produce the whirring sounds.

Notes on the 5 adaptations of the fetal heart: (adaptations are bolded)

- **umbilical vein (1):**
  - carries blood back towards the liver area from the placenta
  - blood which branches to the left enter the liver
    - takes a while for the blood to emerge
  - blood which branches to the left travels through the ductus venosus
    - allows blood to go from the umbilical vein, through it, and meet up with the inferior vena cava (vein which picks up blood from the extremities and brings it into the heart)
  - slightly oxygenated blood dumps into the right atrium from the inferior vena cava
  - deoxygenated blood enters the heart through the superior vena cava
- **Ductus venosus (2):**
  - shortcut from the umbilical vein, into the inferior vena cava
- blood travels through the right ventricle and pumped towards the lungs
  - inside of the lungs, air sacs are not full of air
  - it is actually full of fluid
  - arterioles pass by the fluid filled sacs
    - these sacs are not particularly oxygen rich
  - to obtain sufficient oxygen
    - hypoxic pulmonary vasoconstriction occurs
      - alveolus helps to constrict the arteriole
      - increases the resistance of the arteriole
      - this happens enough times to create a ton of resistance in the lungs
      - this resistance causes the pressure in the pulmonary artery to increase to very high levels
      - for forward flow, there subsequently be much more pressure in the right ventricle
      - subsequently, there must be a lot of pressure in the right atrium.
      - these pressures, especially the right atrial pressure, such that they are a lot higher than the pressure in the left atrium
      - subsequently, blood now flows across the foramen ovale directly from the right to the left atrium
- **foramen ovale:**
  - allows blood to go from one atrium over to the other
  - some blood continues into the RV from the RA, but blood now goes across into the LA as well
  - at the same time that blood is going across, we have not a ton of blood coming back from the pulmonary veins (high resistance)
  - from the LA, blood travels in the following order: LA-->LV-->Aorta-->rest of the body
- **Ductus arteriosus:**
  - a little vessel connection between the pulmonary artery and the aorta
  - allows blood to go from the pulmonary artery to the aorta
  - the pulmonary artery has very high pressure--> blood goes to the lower pressured aorta
  - this helps explain why not so much blood from the pulmonary arteries come back through the pulmonary veins (a sizeable amount of blood transfers to the aorta)
- **Umbilical artery:**
  - brings blood back to the placenta
  - the placenta has a very low resistance--> this is why a lot of blood flows through the umbilical artery
- this is how blood flows in the fetus