NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

That's Not Red Beets!

A Cardiovascular System Review

by

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Part I – Not Your Average Diaper Change

Nathan laid six-month-old Henry on the changing table, held his breath, and opened the potent-smelling diaper. He reached for the baby wipes but paused when he noted a reddish color to Henry's stool. It certainly didn't look like Henry's typical bowel movement, but Nathan wasn't about to poke at it. He quickly finished changing Henry and called to his wife.

"Alison, has Henry had any other poop that looked like this?" Nathan gingerly unwrapped the dirty diaper to show her.

"Yeah, it was kind of that color this morning. But I fed him pureed red beets last night and the same thing happened the last time he ate them." Now that Henry was starting to eat solid food, Alison had grown used to more colorful diaper contents.

Henry fell asleep in his crib, but his crying woke his parents several hours later. Alison noted that he repeatedly kicked his legs and then drew them up to his abdomen, like he was in pain. "Not colic again," Alison mumbled to herself.

"Poor little guy." Nathan rubbed Henry's abdomen to soothe him, but Henry's crying turned to shrieking. Eventually, he calmed down and fell asleep again, but Alison agreed with Nathan that Henry's episodes of abdominal pain seemed to be increasing in frequency and severity.

The next morning, Henry was fussy and seemed to be suffering from another bout of colic. Nathan blearily began to change Henry's diaper but woke up in a hurry; the diaper was full of blood and in the middle of it was a large, jelly-like mass that Nathan assumed was a clot.

Alison raced into the nursery in response to Nathan's panicked shouts. She dropped her travel mug of coffee when Nathan showed her the diaper.

"I don't know what's wrong, but red beets didn't cause this!" he gasped.

"Find the car keys," Alison said as she picked up Henry and raced for the door. "We need to go to the ER!"

It was a little more than an than an hour later that Dr. Wolff checked Henry's vital signs again and gently pushed on his abdomen. She was looking at a very pale, lethargic baby whose most recent diaper was filled with a small amount of stool surrounded by material that looked like dark red currant jelly. The bleeding seemed to be getting worse.

She turned to Alison and Nathan. "I've ordered some blood tests and an ultrasound of his belly and the results should be back very soon. I'm sure that will get us closer to figuring out how to help Henry."

Questions

1. Dr. Wolff ordered the following tests. For each test, predict whether Henry's values will be high, low, or within normal limits and explain your answer. *Note:* The prothrombin time measures the speed of the extrinsic (tissue factor) pathway in blood clotting.

   Table 1. Predicting Henry's results.

Test	*High/Low/Normal*
Hematocrit	
Hemoglobin	
RBC count	
Iron	
Prothrombin time (in seconds)	

2. Predict the effects of the bleeding on Henry's blood volume and blood pressure. Explain your answer.

Part II – Homeostasis in Henry

Dr. Wolff scanned Henry's lab results and his latest vital signs. She wasn't surprised at what she saw; it was consistent with the significant hemorrhaging that Henry continued to experience.

Table 2. Lab results and vital signs.

Test	*Result*	*Normal range*
Hematocrit (%)	17	33–39
Hemoglobin (g/dL)	5	10–13
RBC count (million/ml)	2.1	3.7–5.3
Iron (μg/dL)	19	45–160
Prothrombin time (sec)	12.0	11–14
Blood pressure (mmHg)	94/48	80–100 / 55–65
Heart rate (bpm)	178	100–150

Dr. Wolff ordered a blood transfusion and additional tests to pinpoint the cause of the bleeding. Several hours later, she had an answer for Nathan and Alison.

"Henry has a Meckel's diverticulum, which is a congenital pouch or pocket attached to the small intestine. In many cases, it's lined with the same tissue found in the stomach, which produces stomach acid. The stomach can protect itself from the acid, but the small intestine cannot. The acid has eaten into the lining of the small intestine around the pouch, which is the cause of the bleeding."

Nathan didn't really care about stomach acid in the wrong place, and interrupted Dr. Wolff. "So can you fix it? Will Henry be OK?"

Dr. Wolff smiled. "Yes. It requires surgery to remove the diverticulum, but we have some of the best pediatric surgeons in the area, so Henry will be in good hands."

A week later, Henry was home and able to eat a normal diet. Nathan hesitated when Alison handed him a jar of baby food. "Red beets? I know Henry loves them but I think I need a little more time before I see red poop again. Green beans it is!"

Questions

1. Note Henry's prothrombin time. What conclusions can you make regarding potential causes of Henry's bleeding?

2. Define *anemia*. Based on his blood tests, does Henry have anemia? Explain your answer.

3. a) Although not tested, explain why Henry's level of erythropoietin (EPO) is likely elevated, with reference to the homeostatic mechanism involved.

   b) Why did Dr. Wolff order a blood transfusion if EPO levels are elevated?

   c) Henry has type A-negative blood. Explain why he could receive a transfusion of O-negative blood if the hospital's blood bank could not provide type A.

Henry's continued blood loss will result in reduced blood volume and a subsequent drop in blood pressure. However, the body uses several homeostatic feedback loops to counteract a drop in blood pressure; these loops target the three main factors that affect blood pressure: cardiac output, peripheral resistance, and blood volume. Henry's blood pressure at admission to the ER was only slightly decreased, indicating that the homeostatic mechanisms were able to compensate (if the bleeding continued unchecked, the mechanisms would eventually be overwhelmed). Answer the following questions in light of the homeostatic feedback loops.

Questions

4. Henry has tachycardia, with a heart rate of 178 bpm. Explain why Dr. Wolff was not surprised by his elevated heart rate, with reference to the appropriate homeostatic feedback loop. Does this type of regulation affect cardiac output, peripheral resistance, or volume?

5. Although not performed in this instance, cardiac testing would probably reveal a decrease in Henry's end systolic volume (ESV) and an increase in end diastolic volume (EDV). Explain how these changes help maintain blood pressure, again referencing feedback loops. Would peripheral resistance be affected as well? If so, how?

6. Nathan and Alison noticed that Henry's diapers were not as wet as usual. Describe the homeostatic mechanism that links decreased urine output to regulation of his blood pressure. Which of the three factors (cardiac output, peripheral resistance, blood volume) is/are affected by this feedback loop?

7. Complete Table 3 below. If the condition in the left column increases in activity or level, indicate how cardiac output, peripheral resistance, or blood volume may change (increase, decrease, or no effect). Briefly explain your answers, including whether the effect is direct or indirect.

Table 3. Interplay of cardiac output, peripheral resistance, and blood volume.

Condition	*Cardiac Output*	*Peripheral Resistance*	*Blood Volume*
Sympathetic activity			
Parasympathetic activity			
Antidiuretic hormone (ADH)			
Aldosterone			
Angiotensin II			

Sympathetic activity:

Parasympathetic activity:

ADH:

Aldosterone:

Angiotensin II:

8. *Case summary and integration:* Using Figure 1 below, create a flowchart that shows the homeostatic mechanisms used in an attempt to maintain Henry's blood volume, blood pressure, and blood oxygen levels despite ongoing blood loss.
   a) Show whether blood loss increases or decreases each of the listed variables by placing an up or down arrow in each blank provided in Figure 1.
   b) Below Figure 1, diagram the homeostatic feedback loops that responded to the altered blood volume, pressure, and oxygen levels. Show where they overlap or integrate, and include the following components: *ADH, aldosterone, angiotensin II, baroreceptors, cardiac output, contractility, end diastolic volume, end systolic volume, EPO, erythropoiesis, heart rate, kidneys, peripheral resistance, renin, stroke volume, sympathetic activity, vasoconstriction,* and *venous return.*
   c) Finally, draw dotted lines from the appropriate components in your diagram back to the various stimuli in Figure 1 to complete the feedback loops.

Figure 1. Case summary and integration.