

Service in Somalia: A Case Study in Physiology

by

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Part I –A Bumpy Flight

The first thing I'll eat when I get home is a cheesesteak, thought Emily as she sat sweating in the sweltering hot airport and eating her last bite of Somali takeout food, a pasta and chicken dish she had eaten almost every night for the past month. Tossing her scraps in the trash, she boarded the first leg of her flight to Philadelphia from the Aden Adde International Airport in Mogadishu.

Emily, a premed student in her gap year, had just finished a month-long volunteer trip to Somalia to work with an organization that promoted health and wellness for underserved youth. She loved working with the children in Somalia and felt a calling to serve this country during their humanitarian crisis. It was not an easy experience. She worked nonstop and one particularly aggressive storm this past week had even brought flood waters to her front door; nonetheless, she thought the experience would be pivotal to her pursuit of a career as a doctor.

After sleeping through her first flight, she arrived in London feeling fatigued, dizzy, and thirsty. Shrugging it off she continued to drink water as she had been doing religiously for her entire trip.

Mom always told me to drink a gallon a day so that I'd never get dehydrated, so why am I feeling so poorly? she wondered. She settled into the middle seat and tried to take another nap during the transatlantic flight. She hoped that an eight-hour sleep would help her feel less tired and dizzy. After all, she wanted to look good for her friends and family, who were throwing her a coming home party.

With two hours remaining in the flight, Emily jolted awake. She felt fatigue in every muscle in her body and felt her leg muscles begin to cramp.

"Excuse me, are you feeling okay? Perhaps it's not my place to say but I'm afraid that you don't look too good. I'm a retired nurse, so is there anything I can do to help?" whispered the man next to her as Emily cradled her stomach.

"No, thank you," muttered Emily, as she drew in shaky breaths, thinking about how close she was to reuniting with her loved ones. "I'm fine," she affirmed, more to herself than to him, as she took another tiny sip of water.

Suddenly, Emily felt her stomach turn as she unbuckled her seat belt and jumped over the man, sprinting to the bathroom where she began to vomit for the remainder of the flight.

Questions

1. List the signs and symptoms Emily is experiencing.

2. What effects might excess water intake have on Emily's bodily functions under typical circumstances?

3. If you were the person sitting next to her, what questions would you ask Emily to try to help her understand her symptoms?

4. What do you think is wrong with Emily?

Part II – A Bumpier Landing

Emily groaned as she heard the pilot's voice boom over the plane's loudspeaker: "All passengers please return to your seats and prepare for landing." Emily collected herself, exited the bathroom, and stumbled down the aisle to her seat. She sat down and quickly buckled her seat belt, noticing that the skin on her hands was unusually wrinkled.

After what felt like an eternity and an unbearable bumpy descent, the plane finally came to a jerky stop. Emily gathered her belongings and slowly made her way down the aisle, taking deep and labored breaths with every step.

As Emily walked, she could not help but cradle her stomach, which was cramping even worse than before. As soon as she stepped foot inside the airport, Emily immediately rushed to the bathroom and passed watery diarrhea several times, which appeared unusually white. Feeling very weak, she washed her hands and hardly recognized her own reflection in the mirror, with her sunken eyes and pale complexion. She began to feel that something might be seriously wrong.

Emily collected her bags and made it through customs. She was elated when she saw her parents but noticed that their excitement quickly turned to concern as she got closer to them.

"Emily! Are you feeling okay honey?" her Dad asked in a concerned tone.

"Honestly, not really," Emily responded, and recounted her recent flight experience to her parents. Feeling Emily's forehead and noticing that she did not have any fever, Emily's mom said, "Your temperature feels fine, but I think we should take you to the hospital just to be safe."

"Mom, I just want to sleep, can we please go home instead?" Emily begged. Her parents conceded and started the drive home, promising to take her to the hospital if she got any worse.

Lying down in the backseat of the car, Emily dozed off and did not wake until she was home. Eager to finally sleep in her own bed, Emily got out of the car and started dizzily walking down the driveway towards her house, with her father's support. After only a few steps, Emily lost consciousness and fell into her father's arms. Waking up a few moments later, her parents told her that she had just fainted, and decided to take her to the emergency room.

Questions

1. List any new signs and symptoms Emily is experiencing.
2. Describe how Emily's recurrent diarrhea affects her ion levels.
3. Based on her new symptoms, what do you think Emily may be suffering from?
4. If you were a health care provider in the emergency room, what tests would you run on Emily? Predict the results of those tests.

Part III – A Trip to the Emergency Room

Shortly after Emily arrived at the emergency room, a nurse took her vitals (Table 1).

Table 1. Vital signs for Emily.

<i>Vital Sign</i>	<i>Result</i>	<i>Normal Range</i>
Heart Rate	82 bpm	68–75 bpm
Blood Pressure	83/55 mm Hg	(100–120)/(60–80) mm Hg
Temperature	97.7 °F	97–99 °F

During the next hour, Emily passed two more watery stools, noting their white color each time. As she left the stall to wash her hands, she once again was forced to see her pale skin in the mirror, although this time it was beginning to look almost bluish gray.

After an hour, Emily met Dr. Lunguno, a visiting doctor from Zambia. Emily informed him that she was completely healthy a month ago, as confirmed by a physical done by her family physician, and that she had just returned from a humanitarian trip to Somalia. She added that her symptoms appeared very suddenly on the flight home and progressed rapidly.

After focusing on Emily's symptoms of diarrhea, fainting, muscle fatigue, and deep and labored breathing, Dr. Lunguno ordered blood drawn for lab analysis; some of the results can be seen in Tables 2 and 3. A urinalysis was also ordered, but Emily could not produce any urine.

Table 2. Blood electrolytes for Emily.

<i>Electrolyte</i>	<i>Results</i>	<i>Normal Range</i>
Sodium	131 mEq/L	136–146 mEq/L
Potassium	2.7 mEq/L	3.5–4.5 mEq/L
Chloride	89 mEq/L	96–106 mEq/L
Bicarbonate	14 mEq/L	22–29 mEq/L

Table 3. Blood analysis for Emily.

<i>Test</i>	<i>Result</i>	<i>Normal Range</i>
Red Blood Cells	$5 \times 10^6/\text{mm}^3$	$3.6\text{--}5.5 \times 10^6/\text{mm}^3$
White Blood Cells	$12 \times 10^6/\text{mm}^3$	$5\text{--}11 \times 10^6/\text{mm}^3$
Hemoglobin	16 g/dL	13–18 g/dL
Platelet Count	$280 \times 10^3/\text{mm}^3$	$150\text{--}400 \times 10^3/\text{mm}^3$
Neutrophils	65%	40–60%
Eosinophils	2.5%	1–4%
Basophils	0.5%	0.5–1%
Monocytes	2%	2–6%
Lymphocytes	30%	20–35%
Hematocrit	37%	35–50%

With these test results, Dr. Lunguno asked Emily questions about her time in Somalia, specifically targeting her eating and drinking habits. When asked about how she ate, Emily said, “I was sure to drink a lot of water, although I did have more takeout food than usual.”

While Dr. Lunguno was not sure what to make of the situation, he thought the white-colored stool was odd and decided to order a stool test. Dr. Lunguno was concerned that Emily was showing symptoms of dehydration, so he ordered an intravenous saline drip while they waited for the results of the stool test.

Questions

1. What abnormalities do you notice in the tests that were run? Explain why any values are abnormal.
2. What could be a possible explanation for Emily’s low blood pressure?
3. Use the Nernst equation (below) to calculate the equilibrium potential for potassium in a normal, healthy patient and in Emily. Assume that the ion level in the interstitial fluid is the same as that in the blood plasma, and that the intracellular concentration of potassium is 150 mM in Emily and in the healthy patient.

$$E_{K^+} (\text{millivolts}) = 61 \log_{10} ([K^+]_{\text{out}} / [K^+]_{\text{in}})$$

4. If the difference in the equilibrium potentials in Emily and a healthy patient is indicative of the differences in the membrane potentials, what symptoms can be explained by such a change in Emily’s membrane potential?
5. What may have caused Emily’s electrolyte imbalance?
6. In the results of Emily’s blood analysis, what might her high white blood cell count indicate?
7. With the new test results in mind, what might Emily be suffering from?

Part IV – The Diagnosis

“Okay Emily, the results of your stool test came back, and we detected the bacteria *Vibrio cholerae* in your sample. This means that you contracted cholera during your time in Somalia,” declared Dr. Lunguno.

“Cholera? I thought it was food poisoning this whole time,” said Emily.

“Although your symptoms resemble those of food poisoning, you unfortunately do have cholera, which is a bacterial disease of the small intestine. When I was in medical school in Zambia, many of our patients experienced similar symptoms to yours. The key symptom that clued me in to the possibility of cholera was the watery, white stool you described. These are known as ‘rice-water stools,’ a symptom that is specific to cholera,” responded Dr. Lunguno.

“I thought people only contracted cholera in the 1850s,” said Emily, as she remembered a book she had read in high school about a cholera epidemic in London.

“Sadly, cholera outbreaks still occur all over the world in countries like Somalia. You told me about a flood during your trip, right? That flood most likely contaminated the drinking water with the bacteria, which you then ingested in the water you drank,” explained Dr. Lunguno. “Your parents told me that you want to be a doctor and your trip was part of a gap year you are taking before going to medical school. So, let’s see what you remember about water secretion.”

“I feel like I’m back in physiology lecture when the professor would ask questions of the class,” replied Emily. “As I recall, water secretion occurs in a lot of places in the body like the salivary glands, the airways of the lungs, and the pancreas. I also remember that here’s a protein that uses ATP to move chloride ions across the membrane.” Emily smiled as she began to recall more details. “This chloride ion movement creates diffusion and electrostatic gradients so that sodium and water move across the cells from the tissues.”

“Oh, I see it’s all coming back now,” said Dr. Lunguno with a smile. “It’s called the cystic fibrosis transmembrane regulator channel, or CFTR channel; it’s named after people who suffer from cystic fibrosis. They have a genetic problem that produces a dysfunctional channel, with the result that they can’t secrete enough fluid into their airways. The mechanism is similar for the secretion of fluid into your small intestine, where the bacteria reside.”

Emily smiled. “And I also remember that the channel is turned on by cyclic AMP, which results in phosphorylation of the transporter.”

“Oh, I think you’ll do just fine in medical school,” said the doctor.

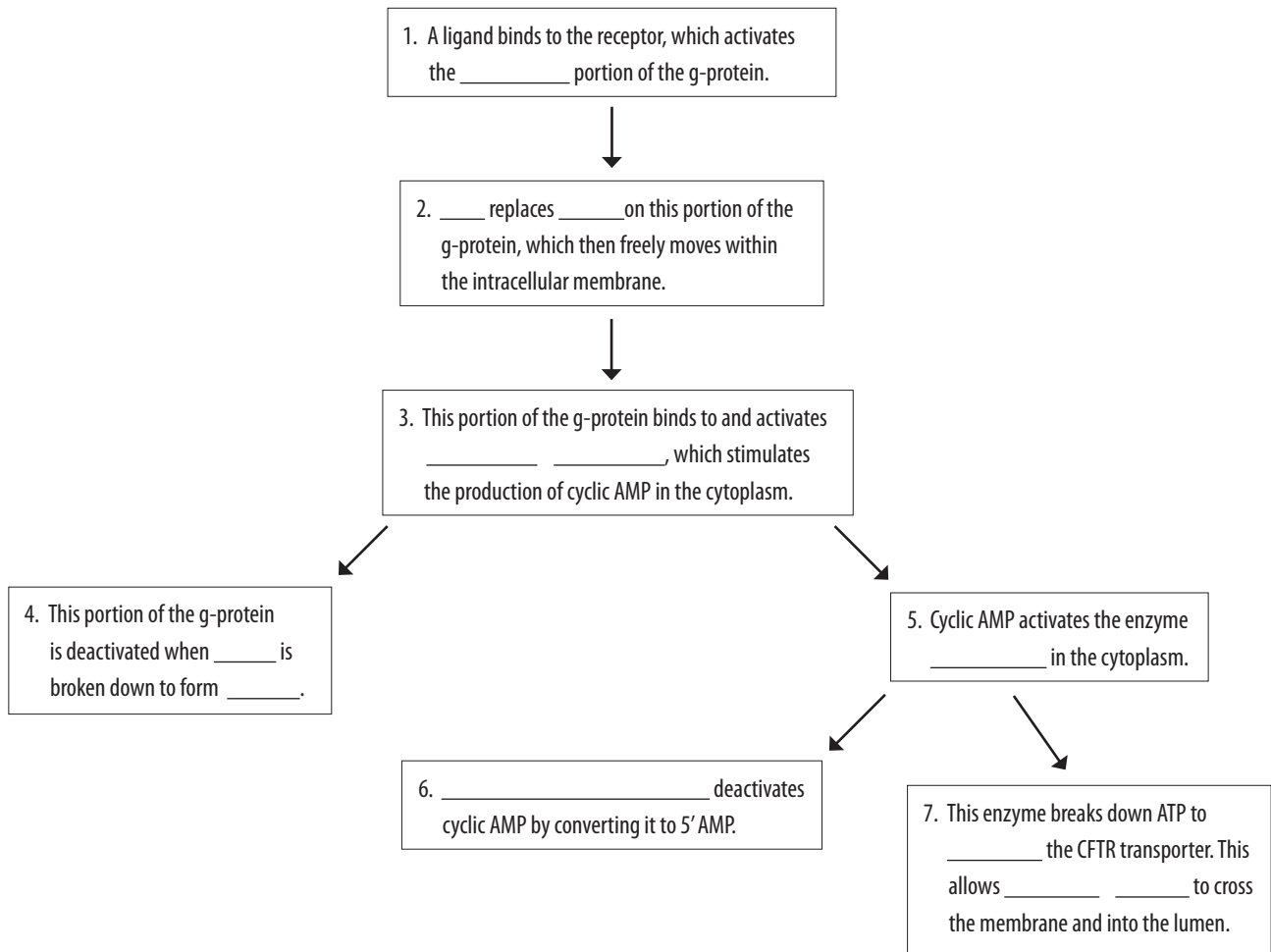
Questions

1. Fill in the flow diagram for the cyclic AMP pathway on the next page (Figure 1). Choose from among the key words below (not all options will be used).

Key words: adenylyl cyclase, ADP, a-kinase, alpha, 5'-AMP, ATP, beta, chloride ions, cyclic AMP, gamma, GTP, GDP, phosphodiesterase, phosphorylate, sodium ions, water.

2. Now look at each step in the completed pathway and explain how cholera toxin could cause excess fluid secretion into the small intestine.

Figure 1. Cyclic AMP flow diagram.



3. What short term and long-term treatments would you recommend for Emily?

Part V –Treatment

“The cholera toxin results in a significant loss of water from your body,” Dr. Lunguno explained. “Since you’re going into medicine, it may interest you to know that the toxin modifies the structure of the alpha subunit of the g-protein, preventing GTP hydrolysis to GDP. In this way, A-kinase is constantly active inside the cells so that the CFTR channel remains open. Chloride ions are constantly leaving the cell, which creates electrochemical and osmotic gradients, allowing ions and water to pour into the small intestine in an uncontrolled manner. This loss of electrolytes and water coupled with the diarrhea explains your low blood electrolytes and dehydration.”

Dr. Lunguno decided to treat Emily with the antibiotic doxycycline together with oral rehydration therapy. He suggested that she return if her symptoms did not improve with three days as certain cholera strains exhibit some degree of antibiotic resistance. Severe dehydration is often treated with fluid replacement with water and electrolytes, which are usually lost through diarrhea. He also recommended that she include potassium-rich foods in her meals and sent Emily home with her parents.

Questions

1. How would an antibiotic reverse the effects of the cholera toxin?
2. Why is it important to use an oral rehydration therapy instead of just recommending water intake?
3. Which hormone is used to maintain normal sodium and potassium levels?
4. Why is it beneficial for Emily’s meals to be potassium-rich?