NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

No Alcohol or Caffeine, Please! GI Sores that Bleed

by
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Part I – Cardiovascular Considerations

I knocked on the door of a charming little house on the street where I had recently rented an apartment. The door eased open and I said, "Hello, my name is Hope, and I'm your new next-door neighbor."

The house belonged to a retired couple, Norma and her husband Sam. Standing in the doorway, I continued, "I go to our local culinary arts college, and I was wondering, would you like to try my specialty dessert, an apple pie?"

Norma smiled, welcomed me in, and offered to make a pot of coffee.

"Coffee would go perfectly with the pie," I said, adding "and thank you... *a latte!"* Thinking myself clever, I grinned broadly.

"That will be fine for us," said Norma quickly, "but not for Sam. He'll have to have a cup of warm milk."

We sat down at their kitchen table, and after some casual chitchat, I learned that Sam had started to drive commercial trucks in 1984 when he was only 20 years old. As he explained, "In those days I averaged four hours of sleep a night and kept myself awake with caffeinated energy drinks. I'd be away for a month and then come home to recoup; those were my catch-up days and I'd drink beer or liquor until I dropped." Sam seemed to recall the time with regret.

"He kept it up until his collision accident and early retirement this year," Norma added with sadness in her eyes. "We're just grateful he's alive!"

"Me too," I replied. I finished my cup of coffee and sensed it was time to go. "Well, so glad to have met you both," I said and headed for the door.

Our friendship developed after several more visits, and a month later I was at their door step when I heard Sam yelling impatiently, "I need my TUMS!" He then ran to the bathroom as he held unto his chest and abdomen as if in severe pain.

"I'm afraid that's his heartburn bothering him again," Norma muttered under her breath as she rushed to help her husband.

"*Now,* please!" Sam continued to yell helplessly for immediate attention, and then fainted.

Shaken and worried, Norma and I drove Sam to the nearest hospital. On the way, she informed me that for several days Sam had been having recurrent bouts of severe, persistent vomiting, accompanied by mild chest and abdominal pain. But this time it had caused him to feel dizzy and lose consciousness. A gurney was rolled out and Sam was carefully placed on it and quickly wheeled into the emergency room. His vital signs were immediately taken and a blood chemistry analysis was ordered. The following results were collected (Table 1).

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Table 1. Vital functions and blood analysis.

Vital Signs	*Sam*	*Normal*
Blood pressure	90/50 mmHg	120/80 mmHg
Resting heart rate (RHR)	110 beats per minute	75 beats per minute
Resting breathing rate (RBR)	18 breaths per minute	12–16 breaths per minute
Body temperature	98 °F	97–99 °F
Blood Chemistry Analysis	*Sam*	*Normal*
RBC count	4 M / μL	4.35–5.65 M / μL
Hemoglobin	9.5 mg/dL	14–18 g/dL (males) 12–16 g/dL (females)
WBC	8000 / μL	4500–11,000 / μL
Platelets	300,000 / μL	150,000–450,000 / μL
Erythropoietin (EPO)	32 milliunits / mL	4–26 milliunits /mL
Cardiac troponin (cTn)	2 ng/L	below 14 ng/L
$PaCO_2$	47 mmHg	35–45 mmHg
PaO_2	60 mmHg	75–100 mmHg
$[H^+]$	3.1×10^{-8} Eq/L	4×10^{-8} Eq/L (0.0004 mEq/L)
pH	TO BE CALCULATED	7.4
$[HCO_3^-]$	TO BE CALCULATED	24 mEq/L

Based on the fact that Sam had recurrent bouts of vomiting as Norma reported, the attending nurse immediately started him on an IV of isotonic saline and gave Norma an antiemetic (an anticholinergic) to stop Sam's vomiting. He was to take it orally at a maximum of three times daily, when needed.

Questions

1. What is the purpose of the IV saline (0.9%)? Why is it isotonic?
2. Referring to Sam's blood pressure, what does each number represent? Define each term used.
3. (a) Calculate Sam's mean arterial pressure (MAP). Include the formula used, all calculations, and units.
   (b) Based on your calculation, does Sam's MAP fall within a normal value range? Based on his symptoms and signs, provide the conditions or factors that may have led to his MAP that you calculated. In your response, describe how these factors alter venous return (VR), end diastolic volume (EDV), end systolic volume (ESV), stroke volume (SV), and cardiac output (CO).

Despite lack of medical history on heart disease, heart attack (myocardial infarction [MI]) was initially suspected because of Sam's chest pain. He was administered four 80mg aspirin tablets and an EKG was ordered. His initial EKG recording seemed to indicate the occurrence of a heart attack so he was asked to stay overnight for monitoring.

Question

4. Why was Sam administered aspirin? How does aspirin help to stabilize his condition?

Meanwhile, plasma value of cardiac troponin (cTn), a cardiac marker, was also ordered. Fortunately, this turned out to be below 14ng/L, ruling out MI since troponin levels higher than this are a sign that an MI has occurred within 6–12 hours (see https://www.testing.com/tests/troponin/).

Question

5. (a) What is troponin?
   (b) Other than in the heart, in which other tissue is troponin located?
   (c) What is its function, according to the sliding filament theory from muscle excitation-contraction coupling to relaxation?
   (d) Describe how cTn functions as a marker for MI.

Twenty-four hours later, a second EKG reading and other immediate tests (chest X-ray and computerized tomography [CT] scan readings not provided here), were completed and ruled out the occurrence of a heart attack.

Questions

6. (a) Sam's second EKG turned out to be normal (see Figure 1 below). Identify each waveform in the figure. Describe what electrical activity(ies) each waveform represents.

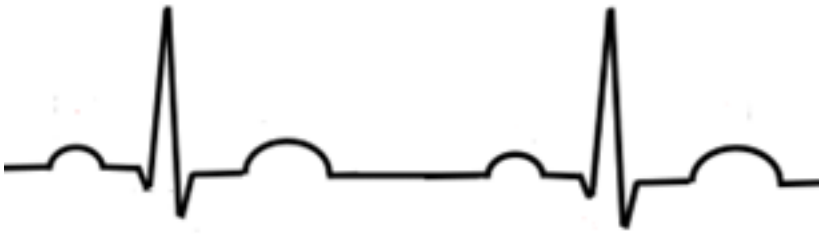

Figure 1. Sam's second EKG.

   (b) Which EKG waveform(s) is (are) produced by slow cardiac myocytes?
   (c) Which EKG waveform(s) is (are) produced by fast cardiac myocytes?

7. What might an EKG recording show if an MI occurred? Which wave or interval would appear elevated?
8. Based on Sam's RHR, calculate his R-R interval. Include the formula used, all calculations, and units.
9. (a) How does the parasympathetic nervous system (PNS) and sympathetic nervous system (SNS) alter HR and the R-R interval? Describe the membrane signaling / coupling mechanism where each system acts.
   (b) Which autonomic subdivision output points to Sam's RHR?
   (c) Explain how Sam's HR attempt to correct his MAP.
10. Describe how Sam's kidneys would attempt to control his hypovolemia, circulatory shock, and MAP (refer to Question 3). Include in your answer the role of the renin-angiotensin-aldosterone-ADH system along with ANP.

Part II – Respiratory Gases and Regulation of Respiration

Questions

11. In what forms are the respiratory gases normally transported by the blood? Specify two forms for O_2 and three forms for CO_2.
12. Based on Sam's blood analysis, what would explain his dizziness and loss of consciousness? What would explain his breathing rate? Justify your response. In your justification, address the following:
    (a) Which sensory receptors would be activated by these factors?
    (b) Where are these sensors located?
    (c) How will their firing rate be altered by the gas levels?
    (d) To which control center would they relay their impulses and how will the control center respond?
    (e) What respiratory muscles will be activated?
    (f) Overall, how would these chemicals impact his respiration rate?
13. (a) Explain how and why Sam's P_aCO_2 level shift the oxyhemoglobin saturation curve.
    (b) Draw a fully labeled graph to depict this.
    (c) Other than CO_2, list other factors that cause the same directional shift.
14. Referring to Sam's blood analysis, explain why his erythropoietin level is elevated. How would this elevated level alleviate his respiration rate and regaining consciousness?
15. As the SNS output altered Sam's HR, how would this SNS output impact his alveolar ventilation rate? In your response, answer the following:
    (a) What neurotransmitter (NT) and corresponding membrane receptor are involved?
    (b) Where would the NT exert effects in the respiratory airway (i.e., target tissue)?
    (c) Describe the NT and membrane signaling cascade.
    (d) How does the NT alter the activity of its target tissue?
    (e) How specifically would this impact alveolar ventilation?

When Sam regained consciousness, he rested and requested some water or food, and Norma helped him to sit up. While sitting, Sam started to vomit again. He ejected vomitus and his stool was of ground coffee color.

Upon further questioning, Sam admitted that he had been a chronic alcohol drinker without food during his drinking bouts. He also shared that he would commonly drink five-hour energy drinks high in caffeine content in order to keep him awake while driving long distances.

Upper endoscopy was immediately ordered, which confirmed that his stomach lining had bleeding ulcers. An image of a stomach model with gastric ulcer (Figure 2) and an endoscopy photo of ulcers similarly found in Sam's stomach lining (Figure 3) are shown below (see next page).

Upon confirmation that Sam was suffering from upper gastrointestinal bleeding (UGIB), he was prescribed a proton pump inhibitor (PPI). He was given a regimen of an IV PPI 80-mg bolus followed by a continuous infusion of 8 mg/hr for 72 hours.

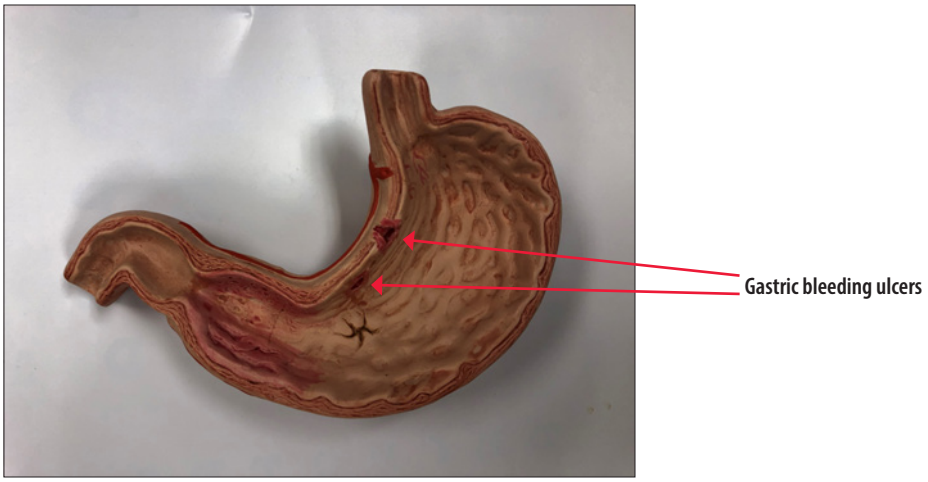

Figure 2. Gastric model with bleeding ulcer. *Credit:* Model by 3B Scientific, photo by Jill Bennett-Toomey.

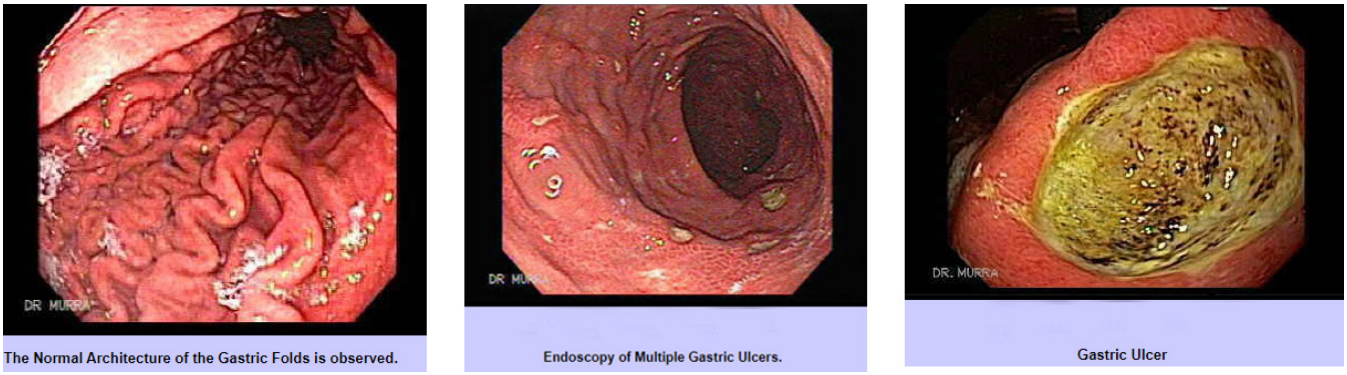

Figure 3. Endoscopy photos of normal stomach lining (left panel), multiple gastric ulcers (middle panel), and giant gastric ulcer (right panel), similarly found in Sam's stomach lining. *Credit:* Images courtesy of Julio Murra-Saca, El Salvador Atlas of Gastrointestinal Video Endoscopy, https://www.gastrointestinalatlas.com, used with permission.

Part III – Gastrointestinal Function Assessment

Questions

16. Draw and fully label the layers of a cross section of a generalized GI wall. Create and complete a table like the one below (Table 2; you will need more rows) indicating each layer's histological makeup. Provide at least one function for each layer, sublayer, or plexus. Start with the outermost layer and work toward the innermost.

Table 2. Histological makeup and function of GI layers.

Name of layer or sub-layer	*Histological makeup*	*Function*

17. Based on GI wall histology (see your response for Question 16):
    (a) Which layer(s) is (are) are possibly involved in contributing to Sam's chest and abdominal pain? Describe how the pain may arise.
    (b) How far into the layers must the gastric ulcers penetrate to cause blood-laden stool or vomitus? Why do you think so?
18. Based on normal gastric structures and functions, how could gastric ulcers develop? Make sure to mention GI glandular enterocytes involved.
19. Based on your answer in Question 17 and 18 and Sam's drinking habits, how could his gastric ulcers have developed?
20. How would a proton pump inhibitor help treat gastric ulcers? Include in your response a labeled drawing of the cell where the medication acts. In your drawing, include the carbonic anhydrase reaction and how its products are transported across the apical and basal membranes.
21. (a) Why and how would an H-2 receptor blocker promote healing of gastric ulcers? Include in your response a labeled drawing of the glandular cell where the medication acts. In your drawing, include the carbonic anhydrase reaction and how its products transport proteins on apical and basal membranes.
    (b) Other than blocking H-2 receptors or using proton pump inhibitots, propose other potential drugs that may reduce HCl secretion. The specific name of a drug is not necessary. Simply justify its potential efficacy by describing its mechanism of action.
22. Based on Sam's profuse and bleeding ulcers, would his plasma pH level be acidic or basic?
23. Does your prediction of Sam's blood pH level in Question 22 oppose or support the *cellular level of activity* responsible for the patient's profuse vomiting or UGIB? (See your response to Question 20.) Describe the cellular mechanisms and transporters that produce the change in arterial pH.

Sam was slowly put on a diet starting with soft food and clear drinks, and his bowel movements observed closely. His stool started to assume a light brown color and normal consistency.

Oral PPI was to be continued for ten days. Before discharge, the dietician met with Sam and advised him to eat three small meals and three snacks evenly spaced throughout the day, and avoid periods of hunger or overeating. He was also advised to cut down on caffeine-containing foods, spicy foods, and acidic foods. Norma took good notes of these food restrictions.

Questions

24. Sam was advised to eat three small meals and three snacks evenly spaced throughout the day, and avoid periods of hunger or overeating. Provide an explanation.
25. Sam was also advised to cut down on caffeine-containing foods, spicy foods, and acidic foods. Why?

After two months, Sam underwent a second endoscopy which showed that his gastric ulcers had healed nicely. Another round of blood chemistry testing revealed normal RBC count, hemoglobin, PCO_2, PO_2, and plasma pH. His vitals were now in good order as well.

Passing by their house one day as I was jogging, I saw Sam out in the yard. "Sam, you're looking great! How are you feeling now?"

"Feeling stronger every day, Hope. No more chest or abdominal pains," Sam replied energetically, "and I had an excellent lab report that calls for celebration with another apple pie!"

"Sounds great, but no coffee please!" Norma stressed affectionately.

Questions

26. (a) With healing from gastric ulcers, gastric function would improve for the initial digestion of which macronutrient?
    (b) What enzyme is needed for its digestion to occur in the stomach?
    (c) Which specific cell produces and secretes the inactive form of this enzyme? How is this enzyme activated?
    (d) How is the optimal pH requirement of this enzyme similar to or different from other GI enzymes?
27. (a) Gastric digestion of the macronutrient (refer to your response for Question 26) is finally completed in what specific segment of the intestinal tract?
    (b) What are the absorbable products resulting from complete digestion of the macronutrient? Where are these products absorbed? What specific membrane transporters are involved? (*Hint:* a labeled drawing may be helpful).
    (c) How is their absorption process similar or different from the absorption process for the two other macronutrient categories of absorbable products?
28. What additional dietary and lifestyle modifications would be suggested to manage Sam's chest pain and heartburn due to gastric ulcer (UGIB)?

Part IV – Acid-Base Homeostasis and Renal Physiology

Questions

29. Referring to Sam's blood analysis, calculate his plasma pH and [HCO_3^-]. Show all of your work. Do these calculations match your prediction? (See your responses for Questions 22 and 23.) What simple acid-base disorder is Sam possibly suffering from?
30. (a) How would the plasma pH you calculated above influence respiration rate? Explain your answer.
    (b) Compare your predicted respiratory rate to Sam's rate. Are they in agreement? Explain.
31. Describe the features (include transport proteins on apical and basal borders and intracellular reactions) of different nephron cells (provide the specific name and location in the nephron) that would help to compensate for Sam's acid-base condition.

Part V – Integrating the Organ Systems

Question

32. Construct a concept map or a flowchart that integrates the anatomy and physiology of body systems that are assessed in analyzing the case study.