

Stubborn Grandma Mimi: Acid-Base Balance in Chronic Kidney Disease

by

Sheri L. Boyce

Department of Biological Sciences

Messiah College, Mechanicsburg, PA

Part I – Mimi’s Decline

The mountain wind rattled the window of the small cabin as Drew sifted through the papers covering the kitchen table, looking for his physiology notes. Instead of his blue notebook, a pink sheet of paper from Mountain View Labs caught his eye.

A closer look showed it to be his 73-year-old grandmother’s lab report from some recent blood tests. Mimi had protested all the way to the appointment and all the way home, but Drew had insisted that if he came home for Thanksgiving break, then she was going for the check-up that she had put off for far too long. Mimi had chronic kidney disease, and the doctors wanted her to start dialysis more than a year ago. Not surprisingly, his stubborn Kentucky-born-and-raised grandmother had refused. She was not a good candidate for home dialysis and the nearest dialysis clinic was an hour away. She didn’t drive much because of cataracts, and there was no one else to take her.

Drew had immediately offered to delay his junior year at the University of Kentucky to stay home and care for her. Mimi was adamantly opposed. “You will stay in school, Andrew Paul Killian! The best way out of these mountains is college, and you’re not dropping out because of me.” Even after Drew discovered the county offered senior citizens free transportation to medical appointments, she shook her head. “God the Almighty will take me home when He’s ready, dialysis or not.” Mimi had raised Drew since the age of three, and he knew when she made up her mind, no one on Earth could change it.

Drew glanced at Mimi as she watched TV. He knew her kidney disease was advancing. He had noticed over the summer that she tired easily and her feet and ankles were badly swollen. She had always loved to debate politics with anyone who dared, but now she had trouble keeping track of conversation. Last week she only picked at her turkey and cranberry sauce, saying that she was too nauseated to eat much. She blamed it on the doctor scaring her about her high blood pressure at the appointment the day before, but Drew saw how baggy her clothes were and knew she hadn’t been eating much for quite some time.

Drew started to scan the lab report, thinking his physiology class might help him understand the results. He had just enough time to note that Mimi’s blood urea nitrogen (BUN) was 208 mg/dL and creatinine was 15 mg/dL before she interrupted him.

“Drew, there’s a *Star Wars* marathon starting!” She patted the sofa beside her. “Bring the rest of the snickerdoodle cookies and watch with me.” Drew found it hard to resist *Star Wars* or Mimi, so he laid the test results aside and spent the rest of the evening cheering for Luke and the Jedi.

The next morning Drew packed his car for the drive back to Lexington. He found his physiology notes, but Mimi had squirreled away the lab results. When he asked, Mimi flapped her hands at him. “Pfffft, stop worrying! You just keep calling every morning to check on me like you have been. And Jimmy lives right over the hill. I’ll call him if I need anything.”

Drew shook his head. Jimmy Seavers was at least a decade older than Mimi and relied on two canes to walk. He didn’t know how much help Jimmy would be, but Mimi was shooing him into the car to avoid any further protest. He hugged her long and hard, and reluctantly headed down the mountain road.

Questions

1. Mimi has many of the classic signs and symptoms of chronic kidney disease, including edema of the lower extremities, nausea and lack of appetite, fatigue, hypertension, and elevated blood urea nitrogen (BUN) and creatinine.
 - a. BUN is the byproduct of protein metabolism and creatinine is produced during muscle activity. Look up the normal ranges for BUN and creatinine, and fill in the table below, including the units. Based on these values, would you classify Mimi’s kidney disease as relatively mild or severe?

	<i>Mimi’s results</i>	<i>Normal range</i>
<i>Blood urea nitrogen (BUN)</i>		
<i>Creatinine</i>		

- b. The graph in Figure 1 below shows the relationship between BUN and creatinine levels and glomerular filtration rate (GFR). What is the normal range for GFR? Use the graph to estimate Mimi’s GFR. Does the estimate agree with your answer to Question 1a above?

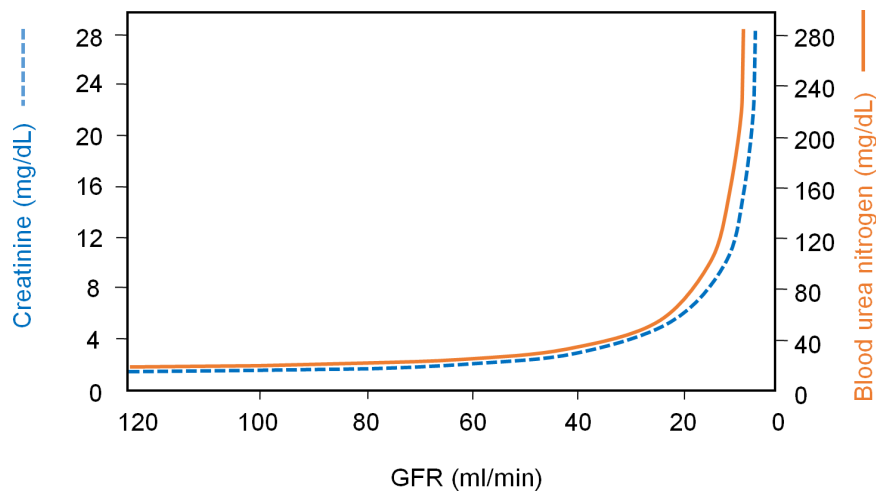


Figure 1. Glomerular filtration rate (GFR) compared to creatinine and (BUN) levels. Adapted from Horowitz, 2019, <<https://emedicine.medscape.com/article/2054342-overview#a4>>.

- c. Based on the graph, what do you observe regarding the relationship between GFR and levels of BUN and creatinine in the blood? Why should BUN and creatinine levels not be used as a sole means of estimating GFR?

2. Consider the common conditions that produce metabolic acidosis and alkalosis.
- Which imbalance does Mimi likely have? Predict how the renal secretion/reabsorption of hydrogen and bicarbonate ions could change (increase or decrease) to produce this condition.

- Based on your answer to Question 2a, use the equation below to predict whether Mimi's pH, bicarbonate ion, and P_{CO_2} levels will increase or decrease compared to normal (disregard any compensation). Explain your answers.



- Describe the compensation provided by Mimi's respiratory system. What effect will this have on her P_{CO_2} ?

Part II – Mimi’s Crisis

Several weeks later, Drew walked out of his last lecture of the fall semester. On the way to the library, he called Mimi for their usual 9:00 A.M. check-in. Instead of hearing her answer with her sassy “No, I’m not dead yet!”, the phone rang and rang before going to voicemail. Drew wasn’t too worried; sometimes she forgot to put her phone in her pocket and couldn’t find it in time to pick up. He tried again 15 minutes later, but still no answer. Thirty minutes and no answer. Now he was worried. Mimi had mentioned feeling feverish and achy yesterday; what if she had gotten worse? When he couldn’t reach Jimmy Seavers either, Drew finally called the police and asked them to do a courtesy check. Mimi would pitch a fit if nothing was wrong, but Drew wasn’t taking any chances.

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Later that day, Drew watched as a ventilator made Mimi’s chest rise and fall. A police officer had found Mimi unresponsive on the couch, and she was taken to the local hospital. When Drew found Mimi in the ER, she was still unresponsive and connected to more tubes and wires than he could count. A nurse explained that Mimi had severe pneumonia, likely a complication of the flu. Typical Mimi, Drew thought, not letting on how sick she was so I wouldn’t worry. Mimi was soon moved to the ICU, where Drew now sat squeezing her hand and hoping for a response.

He noticed some white crystals covering Mimi’s cheeks and brushed at them just as Dr. Perez came in to check on Mimi and review the latest bloodwork. “Uremic frost,” she said, pointing at the crystals. “It’s unusual, but it happens when someone has severe kidney disease that has gone untreated for a long time. I see that your grandmother wasn’t undergoing dialysis?”

Drew rubbed a hand over his face. “It’s complicated; access to the clinic was difficult, and Mimi doesn’t like to rely on other people and... well, she’s just plain stubborn.”

Dr. Perez nodded. “Unfortunately, her kidneys have failed completely, and her bloodwork has me very concerned.” When Drew asked to see the test results, she pointed out the important values. “Her pH is 6.74, P_{CO_2} is 50 mmHg, and bicarb is 5 mmol/L.”

Drew’s physiology class had just covered acid-base balance, and he felt his stomach drop to the floor. “Those numbers are terrible, aren’t they? I mean, 6.74? Can people even live with a pH like that?”

Dr. Perez paused before speaking, and looked directly at Drew. “Mimi’s condition is critical. She has a severe case of pneumonia, and her lungs are full of fluid, which hinders gas exchange in the alveoli. At her age, that alone is serious, but on top of her renal failure... I’ll be straight with you. We’re doing everything we can, but I think it’s unlikely she’ll make it through the night. I’m very sorry.”

Stunned, Drew sank into the bedside chair; he wasn’t aware when Dr. Perez finished her exam and left. Drew took Mimi’s hand again and smoothed her hair, trying to imagine how his life would change without her.

Questions

1. The white crystals on Mimi’s cheek are uremic frost, which is a manifestation of azotemia. Use a reliable reference to define azotemia (in your own words), then explain how uremic frost is related.

2. Look up the normal ranges for blood pH, P_{CO_2} , and HCO_3^- and fill in the following chart, including units.

	<i>Mimi's results</i>	<i>Normal range</i>
pH		
P_{CO_2}		
HCO_3^-		

3. Recall your prediction of Mimi's P_{CO_2} with respiratory compensation (see Part I, Question 2c).
- How does her current P_{CO_2} compare? Explain your observation.
 - Recall your prediction of Mimi's pH in Part I (before she developed pneumonia). How does her current pH compare? Explain your observation.
4. Are her bicarbonate levels abnormally low or high? Explain your observation.