

NephSAP, Volume 16, Number 1, March 2017—Electrolytes and Acid-Base Disorders

1. A 67-year-old woman with chronic systolic heart failure and stage 3a:A1 CKD is evaluated for persistent congestive symptoms despite recent initiation of furosemide 2 weeks ago. During the first week after initiation of furosemide, the weight decreased by 4 kg. Over the past week, however, her weight has remained stable, and she continues to have orthopnea and dyspnea on exertion. Medications are furosemide at 40 mg daily, lisinopril at 30 mg daily, and spironolactone at 25 mg daily. On physical examination, the BP is 115/80 mmHg, and the pulse rate is 68/min. The jugular venous pressure is 8 cm H₂O. There are bibasilar crackles and 2+ leg edema. Laboratory studies show sodium of 134 mEq/L, potassium of 5.0 mEq/L, chloride of 96 mEq/L, total CO₂ of 28 mmol/L, BUN of 34 mg/dl, and creatinine of 2.1 mg/dl (increased from 1.8 mg/dl 2 weeks ago). A urinalysis shows no protein, cells, or casts.

In addition to ongoing assessment of this woman's serum electrolytes and kidney function, which ONE of the following is the MOST appropriate next step in management?

- A. Discontinue furosemide
 - B. Discontinue lisinopril
 - C. Increase furosemide to 80 mg/d
 - D. Increase furosemide to 40 mg twice daily
2. A 72-year-old man with recently diagnosed non-small cell lung cancer is referred for evaluation of asymptomatic hyponatremia. He was recently found to have a serum sodium level of 125 mEq/L, despite adherence to 1.5 L/d of fluid restriction. Review of the medical record indicates that his serum sodium was 139 mEq/L on laboratory studies obtained 1 year ago. He is not on any medications. On physical examination, he is alert and oriented. The BP is 138/82 mmHg, and the pulse is 70/min. He has no edema. The remainder of the examination is unremarkable. Laboratory studies show sodium of 125 mEq/L, potassium of 4.9 mEq/L, chloride of 91 mEq/L, total CO₂ of 24 mmol/L, BUN of 7 mg/dl, and

creatinine of 0.8 mg/dl. His urinary studies show osmolality of 560 mOsm/kg, sodium of 80 mEq/L, and potassium of 60 mEq/L.

In addition to continued fluid restriction, which ONE of the following is the BEST initial treatment for this patient?

- A. Decrease water intake further to 1.0 L/d
 - B. Decrease water intake further to 750 ml/d
 - C. 100 ml 3% saline intravenously over 6 hours
 - D. Furosemide at 40 mg/d plus sodium chloride tablets at 1 g three times daily
3. A 75-year-old man with recently diagnosed pancreatic cancer and hypertension is seen in consultation for hyponatremia. According to family members, he was in his usual state of health until the day before admission, when he developed progressive confusion and agitation. His medications are lisinopril and chlorthalidone. Review of his medical record shows that his serum sodium level was 134 mEq/L 6 weeks ago. On physical examination, he is intermittently agitated and disoriented. The BP is 140/85 mmHg, and the pulse rate is 85/min. There are no postural changes in BP or pulse. The neurologic examination shows no focal deficits. The remainder of examination is unremarkable. Laboratory results show sodium of 115 mEq/L, potassium of 3.9 mEq/L, chloride of 80 mEq/L, total CO₂ of 25 mmol/L, BUN of 6 mg/dl, creatinine of 0.8 mg/dl, glucose of 106 mg/dl, calcium of 9.0 mg/dl, and serum osmolality of 236 mOsm/kg. The urine osmolality is 380 mOsm/kg, the urine sodium is 40 mEq/L, and the urine potassium is 30 mEq/L.
- In addition to fluid restriction and discontinuing chlorthalidone, which ONE of the following is the MOST appropriate next step in management?**
- A. No additional interventions
 - B. 3% saline to increase SNa⁺ 4–6 mEq/L
 - C. Tolvaptan
 - D. Furosemide plus intravenous isotonic saline with potassium chloride at 40 mEq/L

4. Which ONE of the following is MOST likely to be associated with the development of hyponatremia in individuals involved in heavy exercise?

- A. Urine sodium plus urine potassium equal to 36 mEq/L
- B. Urine osmolality of 200 mOsm/kg after exercise
- C. Weight gain >3 kg after exercise
- D. An increase in urinary osmolality during exercise

5. A 70-year-old man with refractory nocturnal polyuria is evaluated 1 week after starting desmopressin for enuresis. He has heart failure with a preserved ejection fraction that has been well compensated. Optimization of treatment for lower urinary tract symptoms stemming from benign prostatic hypertrophy has failed to control his nocturia. Before starting desmopressin, the first morning void urine osmolality was 286 mOsm/kg. After starting desmopressin, the frequency of nocturia decreased from five to two times per night. On physical examination, he is alert and oriented. The BP is 130/78 mmHg, and the pulse rate is 72/min. An S4 gallop is present. There is trace pretibial edema. The remainder of the examination is normal. Laboratory studies show that the serum sodium level has decreased to 133 mEq/L from a baseline level of 138 mEq/L. The urine osmolality is 526 mOsm/kg.

In addition to close follow-up of the serum sodium level, which ONE of the following is the MOST appropriate management for this man's enuresis, hyponatremia, and heart failure?

- A. Discontinue desmopressin
- B. Discontinue desmopressin plus a 100-ml bolus of 3% saline
- C. Continue desmopressin, decreasing fluid intake in response to thirst only
- D. Continue desmopressin and increase dietary sodium

6. A 46-year-old man with central diabetes insipidus (DI) is evaluated in the emergency department for a 1-day history of generalized fatigue. Over the past 2 weeks, he increased his fluid intake because of an upper respiratory tract infection. His only medication is intranasal desmopressin at 10 μ g twice daily. On physical examination, he is alert and oriented. The remainder of the examination is normal. Laboratory studies show serum sodium of 116 mEq/L, potassium of 3.8 mEq/L, chloride of

82 mEq/L, total CO₂ of 24 mmol/L, BUN of 5 mg/dl, creatinine of 0.7 mg/dl, and glucose of 120 mg/dl. The urine osmolality is 826 mOsm/kg. He is admitted, and desmopressin therapy is withheld. The urine volume subsequently rises to 500 ml/h. A repeat serum sodium level obtained 4 hours after the initial laboratory studies is 124 mEq/L, and the urine osmolality is now 36 mOsm/kg.

In addition to ongoing monitoring of the serum sodium level and neurologic status, which ONE of the following is the MOST appropriate treatment for this patient?

- A. Restart intranasal desmopressin at 10 μ g twice daily
- B. Desmopressin at 4 μ g subcutaneously plus intravenous 5% dextrose in water (D5W) to achieve a serum sodium of 118–122 mEq/L
- C. Restart intranasal desmopressin at 10 μ g twice daily plus a 100-ml bolus of 3% saline intravenously
- D. Start intravenous D₅W at 250 ml/h

7. You are asked to see a 65-year-old woman with stage 3b:A3 CKD from diabetic kidney disease and chronic systolic heart failure in consultation 1 week in advance of elective coronary angiography (CA). Medications are metformin, simvastatin, lisinopril, chlorthalidone, and aspirin. A physical examination shows a BP of 132/80 mmHg. There is trace ankle edema. The remainder of the examination is normal. Laboratory studies show sodium of 138 mEq/L, potassium of 5.2 mEq/L, chloride of 104 mEq/L, total CO₂ of 23 mmol/L, BUN of 32 mg/dl, creatinine of 1.9 mg/dl, and eGFR of 32 ml/min per 1.73 m².

Which ONE of the following is the BEST management recommendation?

- A. Discontinue metformin 2–3 days before CA
- B. Discontinue lisinopril 1 day before CA
- C. Make no changes to the current medication regimen
- D. Discontinue chlorthalidone

8. A 78-year-old man with advanced chronic obstructive lung disease, congestive heart failure, and stage G3b CKD is admitted for treatment of pneumonia. Over the past 3 days, his oral intake has been minimal. His home medications include inhaled fluticasone-salmeterol and furosemide. On physical examination, his breathing is labored,

with use of accessory respiratory muscles. The BP is 96/60 mmHg, the pulse rate is 120/min, and the temperature is 38.1°C. The oxygen saturation is 98% on 2 L/min supplemental oxygen *via* nasal cannula. The jugular venous pressure is <5 cm H₂O. The lung examination shows scattered wheezes and poor air movement. There is no peripheral edema. Laboratory studies show serum sodium of 145 mEq/L, potassium of 3.0 mEq/L, chloride of 100 mEq/L, total CO₂ of 40 mmol/L, BUN of 45 mg/dl, and creatinine of 2.5 mg/dl (increased from a recent baseline level of 1.8 mg/dl). An arterial blood gas on 2 L/min of supplemental oxygen shows pH 7.47, P_aCO₂ of 55 mmHg, bicarbonate of 38 mEq/L, and P_aO₂ of 65 mmHg. The patient is treated with antibiotics, bronchodilators, and systemic corticosteroids. You are asked to help manage his acid-base disorder.

In addition to potassium supplementation and continuous monitoring of the volume status, which ONE of the following is the MOST appropriate management strategy for this man's acid-base disorder?

- A. Discontinue furosemide and begin intravenous 0.9% saline at 125 ml/h
 - B. Replace furosemide with acetazolamide at 500 mg daily
 - C. Add spironolactone at 50 mg twice daily
 - D. Ammonium chloride at 20 mEq in 1 L 0.9% saline intravenously over 24 hours
9. A 50-year-old man with bipolar disorder is referred for persistent polyuria. He had previously been maintained on lithium for 15 years, but it was discontinued 6 months ago because of a progressive rise in the serum creatinine level from 0.8 to 1.4 mg/dl. A water deprivation test 2 months ago was consistent with nephrogenic DI. He is now maintained on hydrochlorothiazide at 25 mg daily. Laboratory studies show serum osmolality of 298 mOsm/kg, sodium of 141 mEq/L, potassium of 3.9 mEq/L, chloride of 102 mEq/L, total CO₂ of 24 mmol/L, BUN of 28 mg/dl, creatinine of 1.4 mg/dl, and glucose of 90 mg/dl. A 24-hour urine collection shows a volume of 4.0 L, a sodium of 70 mEq/L, a potassium of 26 mEq/L, and a urine osmolality of 240 mOsm/kg. A urinalysis shows specific gravity of 1.006, trace protein, and negative glucose.

Which ONE of the following is the MOST appropriate next step in management?

- A. Increase hydrochlorothiazide to 25 mg twice daily
 - B. Add amiloride at 10 mg daily
 - C. Add intranasal desmopressin at 10 µg daily
 - D. Decrease dietary sodium intake to 2–3 g/d
10. A 53-year-old man is admitted to the intensive care unit with urosepsis. His serum sodium level has risen slowly from 140 to 155 mEq/L over the past 5 days. He is lethargic, but responds appropriately to simple questions. His BP is 130/70 mmHg off vasopressor agents. The pulse rate is 80/min. His weight is 60 kg. The remainder of the examination is unremarkable. His current urine output is 2 L/d. Laboratory studies show serum osmolality of 329 mOsm/kg, sodium of 155 mEq/L, potassium of 3.6 mEq/L, chloride of 122 mEq/L, total CO₂ of 20 mmol/L, BUN of 36 mg/dl, creatinine of 1.5 mg/dl, and glucose of 88 mg/dl. Urinary studies show sodium of 60 mEq/L, potassium of 40 mEq/L, and osmolality of 315 mOsm/kg.
- Assuming insensible water losses of 0.8 L/d, which ONE of the following is the total amount of free water that should be administered to decrease the serum sodium to 145 mEq/L over the next 24 hours?**
- A. 4.0 L
 - B. 3.2 L
 - C. 2.3 L
 - D. 1.6 L
11. A 25-year-old woman marathon runner becomes confused after completing the run in 5 hours and 15 minutes. Her serum sodium at end of the run is 125 mEq/L. On physical examination, she is obtunded. The BP is 140/80 mmHg, and the pulse rate is 86/min. Skin turgor is normal. The remainder of the examination is normal.
- Which ONE of the following is MOST important in the pathogenesis of her hyponatremia?**
- A. Excessive water intake and retention
 - B. Sequestration of water in the gastrointestinal tract
 - C. Sodium chloride loss in sweat
 - D. Decreased extracellular fluid volume
12. A 70-year-old woman with type 2 diabetes mellitus, stage G3b CKD, and hypertension is admitted

for treatment of hypovolemia after 1 week of recalcitrant nausea, vomiting, and diarrhea. Her medications include metformin at 500 mg twice daily, irbesartan at 150 mg/d, and chlorthalidone at 25 mg daily. On physical examination, she is alert, oriented, and does not appear toxic. The skin turgor is reduced. She is afebrile, with a BP of 100/60 mmHg and a pulse rate of 112/min. The remainder of the physical examination is unremarkable. Laboratory studies show serum sodium of 143 mEq/L, potassium of 4.9 mEq/L, chloride of 112 mEq/L, total CO₂ of 16 mmol/L, BUN of 46 mg/dl, creatinine of 2.2 mg/dl (increased from a recent baseline level of 1.4 mg/dl), and glucose of 102 mg/dl. A complete blood count shows a leukocyte count of 5600/ μ l, hemoglobin of 13.3 g/dl, and platelet count of 356,000/ μ l. An arterial blood gas on ambient air shows pH 7.32, P_aCO₂ of 32 mmHg, bicarbonate of 18 mEq/L, and P_aO₂ of 94 mmHg. The arterial lactate level is 4 mmol/L. Urinalysis shows specific gravity of 1.018, trace protein, and no glucose. The urine sediment is bland. The urine sodium level is <10 mEq/L.

In addition to discontinuing her current medications and volume expansion with isotonic crystalloid, which ONE of the following is the next BEST step in management?

- A. Obtain a serum metformin level to guide further therapy
- B. Continuous RRT at 25 ml/kg per hour
- C. Acute hemodialysis with a blood flow of 450 ml/h for 4 hours
- D. Observation of clinical status after correction of hypovolemia

13. Compared with furosemide, which ONE of the following statements is CORRECT regarding torsemide?

- A. Torsemide has increased bioavailability and a longer half-life
- B. Torsemide inhibits proximal tubular sodium reabsorption
- C. Torsemide is more kaliuretic
- D. Torsemide is more potent because it directly inhibits the activity of the epithelial sodium channel (ENaC) in the collecting duct

14. You are asked to make management recommendations for a 70-year-old woman with recently diagnosed SIADH. She is asymptomatic and has

a normal physical examination. Laboratory studies show serum sodium of 128 mEq/L, potassium of 4.0 mEq/L, chloride of 94 mEq/L, total CO₂ of 24 mmol/L, BUN of 6 mg/dl, creatinine of 0.6 mg/dl, glucose of 80 mg/dl, and osmolality of 263 mOsm/kg. Urine studies show sodium of 40 mEq/L, potassium of 22 mEq/L, and osmolality of 250 mOsm/kg. The daily urine volume is 2 L. You recommend fluid restriction and liberalization of dietary sodium intake.

Assuming 0.8 L insensible losses of water per day, which ONE of the following is the maximum amount of solute-free water that she can drink without a further decrease in the serum sodium?

- A. 0 L
- B. 1.8 L
- C. 2.3 L
- D. 2.8 L

15. You are asked to see a 65-year-old woman with chronic obstructive lung disease and congestive heart failure in consultation for alkalemia. She was admitted with 2 days of increased dyspnea, fever, nausea, vomiting, and cough. Medications are ipratropium, furosemide, and enalapril. On physical examination, she is tachypneic, with a respiratory rate of 24/min. The BP is 90/60 mmHg, the pulse rate is 108/min, and the temperature is 38.3°C. The lung examination shows right basilar crackles. There is no edema. A dense right lower infiltrate is seen on a chest radiograph. Laboratory studies show sodium of 140 mEq/L, potassium of 3.4 mEq/L, chloride of 85 mEq/L, total CO₂ of 35 mmol/L, BUN of 35 mg/dl, creatinine of 1.2 mg/dl, and glucose of 82 mg/dl. An arterial blood gas on ambient air shows pH 7.45, P_aCO₂ of 54 mmHg, bicarbonate of 36.5 mEq/L, and P_aO₂ of 52 mmHg.

Which ONE of the following BEST describes this woman's acid-base status?

- A. Simple metabolic alkalosis
- B. Metabolic alkalosis and metabolic acidosis
- C. Respiratory acidosis and metabolic alkalosis
- D. Respiratory acidosis, metabolic alkalosis, and metabolic acidosis

16. A 20-year-old woman is referred for hypokalemic metabolic alkalosis. Over the past several years, she has noted progressive worsening of polyuria, thirst, salt craving, weakness, and fatigue. She does not have vomiting and is on no medications. On

physical examination, the BP is 110/70 mmHg, and the pulse rate is 74/min. The remainder of the examination is normal. Laboratory studies show sodium of 140 mEq/L, potassium of 2.2 mEq/L, chloride of 88 mEq/L, total CO₂ of 42 mmol/L, BUN of 12 mg/dl, creatinine of 0.9 mg/dl, glucose of 90 mg/dl, calcium of 9.2 mg/dl, and magnesium of 1.7 mg/dl. The plasma renin activity is 102 ng/ml per hour (reference range =0.6–3.0 ng/ml per hour), and the plasma aldosterone concentration is 56.5 ng/dl (reference range =2–5 ng/dl). Urinary electrolytes are sodium of 45 mEq/L, potassium of 50 mEq/L, and chloride of 60 mEq/L. The urine calcium-to-creatinine ratio is 280 mg/g.

Which ONE of the following is the MOST likely diagnosis?

- A. Primary hyperaldosteronism
 - B. Gitelman syndrome
 - C. Bartter syndrome
 - D. Surreptitious vomiting
 - E. Liddle syndrome
17. A 65-year-old man is evaluated 3 weeks after receiving a deceased donor kidney transplant. He is doing well and asymptomatic. His medications include tacrolimus, mycophenolate mofetil, prednisone, carvedilol, dapson, and acyclovir. On physical examination, the BP is 160/94 mmHg. The allograft is nontender and without bruit. He has trace pretibial edema. The remainder of the examination is normal. Laboratory studies show sodium of 138 mEq/L, potassium of 5.8 mEq/L, chloride of 109 mEq/L, total CO₂ of 18 mmol/L, BUN of 18 mg/dl, creatinine of 1.4 mg/dl, and glucose of 108 mg/dl. A 12-hour tacrolimus trough level is 8 ng/ml. An ultrasound of the kidney transplant shows normal vasculature and no hydronephrosis.

In addition to a low-potassium diet, which ONE of the following is the BEST management of this patient's hyperkalemia?

- A. Reduce tacrolimus to achieve trough levels of 4–5 ng/ml
 - B. Start chlorthalidone
 - C. Start fludrocortisone
 - D. Start sodium bicarbonate
18. A 55-year-old woman with stage G4 CKD due to diabetic kidney disease is referred for management of persistent hyperkalemia. She has been adherent

with dietary potassium restriction. Her medications include insulin glargine, omeprazole, metoprolol, lisinopril, amlodipine, and furosemide. The physical examination shows a BP of 130/82 mmHg, background diabetic retinopathy, and decreased sensation in the feet. The remainder of the examination is normal. Laboratory studies show sodium of 140 mEq/L, potassium of 5.9 mEq/L, chloride of 109 mEq/L, total CO₂ of 22 mmol/L, BUN of 26 mg/dl, creatinine of 4.2 mg/dl, eGFR of 17 ml/min per 1.73 m², glucose of 138 mg/dl, calcium of 8.9 mg/dl, magnesium of 1.8 mg/dl, and phosphorus of 5.4 mg/dl. You prescribe patiromer calcium.

This patient is at risk for which ONE of the following complications related to treatment with patiromer calcium?

- A. Hypomagnesemia
 - B. Hypercalcemia
 - C. Metabolic alkalosis
 - D. Hypophosphatemia
19. A 50-year-old woman is referred for evaluation of new-onset hypertension. Two weeks ago, she noted onset of headache and muscle cramps. She is an avid tea drinker and recently starting drinking an imported tea from Egypt. She has not smoked cigarettes. On physical examination, she is a healthy-appearing woman in no acute distress. The body mass index is 19.5 kg/m². The BP is 220/100 mmHg, and the pulse rate is 88/min. There are no abdominal or flank bruits, and there is no radiofemoral delay. Laboratory studies show sodium of 146 mEq/L, potassium of 2.9 mEq/L, chloride of 104 mEq/L, total CO₂ of 32 mmol/L, BUN of 9 mg/dl, creatinine of 0.6 mg/dl, calcium of 9.2 mg/dl, magnesium of 1.8 mg/dl, and phosphorus of 2.4 mg/dl. Urine electrolytes show potassium of 50 mEq/L, sodium of 45 mEq/L, and chloride of 40 mEq/L. The plasma renin activity is 0.1 ng/ml per hour (reference range =0.6–3.0 ng/ml per hour), and the plasma aldosterone concentration is <1.0 ng/dl (reference range =2–5 ng/dl). The plasma deoxycorticosterone level is normal. The 24-hour urine free cortisol is 170.25 μg/g creatinine (reference range <24 μg/g), the 24-hour urine cortisone is 42 μg/g creatinine (reference range =8–65 μg/g), and the 24-hour urine cortisol-to-cortisone ratio is 4.0.

Which ONE of the following is the MOST likely cause of this patient's hypokalemia?

- A. Decreased activity of 11β -hydroxysteroid dehydrogenase
- B. Liddle syndrome
- C. Cushing syndrome
- D. Ectopic adrenocorticotrophic hormone syndrome

20. An 82-year-old man with stage G5 CKD and hypothyroidism is evaluated during a follow-up visit for hyperkalemia. His medications are amlodipine, furosemide, and levothyroxine. He has decided to forego dialysis in favor of medical management. His serum potassium level is 6.2 mEq/L, despite adherence to a potassium-restricted diet. You prescribe sodium polystyrene sulfonate.

Which ONE of the following would you advise this patient with regard to sodium polystyrene sulfonate therapy?

- A. The frequency of colonic necrosis is approximately 0.1%
- B. It can be safely coadministered with his other medications
- C. There is no evidence supporting its use for the treatment of hyperkalemia in CKD
- D. Use of a sorbitol-free preparation eliminates the risk of colonic necrosis

21. Which ONE of the following MOST likely contributes to the pathogenesis of salt-sensitive hypertension in individuals consuming a low-potassium diet?

- A. Increased aldosterone production
- B. Increased activity of the NCC in the distal convoluted tubule
- C. Increased activity of the ENaC in the aldosterone-sensitive portion of the distal tubule and collecting duct
- D. Inhibition of WNK1 in the distal convoluted tubule

22. A 24-year-old man is evaluated for weakness and recently documented hypokalemic metabolic alkalosis. He indicates that he has always craved salty foods and had intermittent leg cramps since age 15 years old. Over the past 2 months, he noted onset of diffuse myalgias, polyuria, weakness, and worsening leg cramps. He is on no medications and does not have vomiting or diarrhea. On physical examination, his stature is normal. The BP is 118/60 mmHg, and the pulse rate is 88/min. The neuro-

logic examination shows mild diffuse weakness. The remainder of the examination is normal. Laboratory studies show sodium of 142 mEq/L, potassium of 3.2 mEq/L, chloride of 102 mEq/L, total CO_2 of 30 mmol/L, BUN of 9 mg/dl, creatinine of 0.8 mg/dl, glucose of 87 mg/dl, calcium of 9.6 mg/dl, magnesium of 1.4 mg/dl, and phosphorus of 2.8 mg/dl. Urine electrolytes show potassium of 50 mEq/L, sodium of 63 mEq/L, and chloride of 87 mEq/L. The plasma renin activity is 11 ng/ml per hour (reference range = 0.6–3.0 ng/ml per hour), and the plasma aldosterone concentration is 17 ng/dl (reference range = 2–5 ng/dl). A urinalysis shows specific gravity of 1.015, pH 7, and no protein or blood. A comprehensive urine diuretic screen is negative.

Which ONE of the following diagnostic tests is MOST appropriate to perform next?

- A. 24-hour urine collection for potassium
- B. Genetic testing for mutations in the *CLCNKB* gene
- C. Urine calcium-to-creatinine ratio
- D. Fractional chloride clearance in response to hydrochlorothiazide at 50 mg

23. A 65-year-old woman is referred for evaluation of hypokalemia and hypomagnesemia. She recently completed concurrent radiochemotherapy for stage 3 nonsmall cell lung cancer. The chemotherapy regimen included cisplatin plus vinblastine. On physical examination, the BP is 110/60 mmHg, and the pulse rate is 96/min. There are decreased breath sounds at the left lung base. There is no edema. The remainder of the examination is normal. Laboratory studies show sodium of 133 mEq/L, potassium of 3.2 mEq/L, chloride of 101 mEq/L, total CO_2 of 29 mmol/L, BUN of 32 mg/dl, creatinine of 1.3 mg/dl, calcium of 8.9 mg/dl, magnesium of 1.1 mg/dl, and phosphorus of 3.5 mg/dl. The urine sodium is 72 mEq/L, the urine chloride is 56 mEq/L, and the urine potassium is 65 mEq/L. The urine calcium-to-creatinine ratio is 26 mg/g.

Dysfunction of which ONE of the following nephron segments is contributing the MOST to this woman's hypomagnesemia?

- A. The thick ascending limb of the loop of Henle
- B. The medullary collecting duct
- C. The descending limb of the loop of Henle
- D. The early distal convoluted tubule

24. You are asked to see a 60-year-old woman with transfusion-dependent myelodysplastic syndrome hospitalized for weakness and newly documented hypokalemic metabolic acidosis. Her medications are ruxolitinib and deferasirox. The physical examination shows a normal BP and pulse, pallor, no edema, and mild diffuse weakness. Laboratory studies show sodium of 138 mEq/L, potassium of 3.4 mEq/L, chloride of 109 mEq/L, total CO₂ of 19 mmol/L, BUN of 18 mg/dl, creatinine of 1.3 mg/dl, glucose of 86 mg/dl, calcium of 8.0 mg/dl, magnesium of 1.6 mg/dl, phosphorus of 1.1 mg/dl, albumin of 3.8 g/dl, total protein of 6.6 g/dl, uric acid of 2.8 mg/dl, leukocyte count of 2500/ μ l, hemoglobin of 6.3 g/dl, and platelet count of 32,000/ μ l. A urinalysis shows pH 5.0 and trace protein. A venous blood gas shows pH 7.32 and P_vCO₂ of 36 mmHg. The daily urine ammonium excretion is 40 mmol. The urinary phosphate level is 25 mg/dl, and the urine creatinine level is 100 mg/dl. The urine protein-to-creatinine ratio is 400 mg/g, and the albumin-to-creatinine ratio is 30 mg/g. A urine electrophoresis shows low-molecular weight proteinuria. No monoclonal spike is present on urine and serum electrophoresis.

Which ONE of the following is the MOST likely diagnosis?

- A. Hypokalemic distal renal tubule acidosis (type 1)
 - B. Tumor-induced osteomalacia
 - C. Spurious hypophosphatemia
 - D. Bicarbonate loss through the gastrointestinal tract
 - E. Proximal renal tubular acidosis
- 25.** A 38-year-old man is seen in consultation for recurrent kidney stones. He has had symptomatic nephrolithiasis, averaging one stone per year, since age 25 years. Analysis of a recently extracted stone shows that is composed of calcium phosphate. Laboratory studies show sodium of 138 mEq/L, potassium of 4.0 mEq/L, chloride of 108 mEq/L, total CO₂ of 20 mmol/L, BUN of 13 mg/dl, creatinine of 1.2 mg/dl, calcium of 9.1 mg/dl, and phosphorus of 3.2 mg/dl. A urinalysis shows no protein, glucose, or blood. A 24-hour urine collection shows volume of 2.12 L, pH 6.1, calcium of 124 mg (target level, <250 mg), oxalate of 33 mg (target level, 20–40 mg), citrate of 102

mg (target level, >450 mg), uric acid of 392 mg (target level, <800 mg), sodium of 122 mEq (reference range, 50–150 mEq), ammonium of 28 mmol (reference range, 15–60 mmol), and phosphate of 358 mg (reference range, 600–1200 mg).

Which ONE of the following is the MOST likely diagnosis?

- A. Type 4 renal tubular acidosis
 - B. Proximal renal tubular acidosis (type 2)
 - C. Dent disease
 - D. Incomplete distal renal tubular acidosis (type 1)
- 26.** Which ONE of the following patients is at an increased risk for profound metabolic alkalosis and hypovolemia in response to hydrochlorothiazide?
- A. A 20-year-old man with glucocorticoid-remediable aldosteronism (GRA)
 - B. A 23-year-old man with Liddle syndrome
 - C. An 18-year-old woman with sensorineural hearing loss and goiter
 - D. A 74-year-old woman with hypertension on no additional medications
- 27.** A 24-year-old woman with cystic fibrosis is hospitalized for treatment of Pseudomonas pneumonia. Her hospital course is complicated by ileus requiring nasogastric suction. Twelve days into her hospital course, she develops paresthesias and diffuse muscle weakness. Her medications are pancrelipase, fat-soluble vitamins, calcium carbonate, insulin aspart, high-dose ceftazidime, and gentamicin. On physical examination, the BP is 110/80 mmHg, and the pulse rate is 102/min. The lung examination shows inspiratory crackles at the right base. There is no edema. Laboratory studies show sodium of 138 mEq/L, potassium of 2.3 mEq/L, chloride of 93 mEq/L, total CO₂ of 34 mmol/L, BUN of 39 mg/dl, creatinine of 1.3 mg/dl, calcium of 8.4 mg/dl, magnesium of 1.2 mg/dl, and phosphorus of 3.2 mg/dl. A venous blood gas shows pH 7.43 and P_vCO₂ of 53 mmHg. The urine sodium is 78 mEq/L, the urine chloride is 68 mEq/L, and the urine potassium is 52 mEq/L.
- Which ONE of the following is the MOST likely cause of this woman's acid-base abnormality?**
- A. Nasogastric suction
 - B. Gentamicin
 - C. Posthypercapnic alkalosis
 - D. Sodium chloride loss in sweat
 - E. Ceftazidime

28. A 33-year-old woman with Sjögren syndrome is referred for evaluation of recurrent calcium phosphate kidney stones. She has had three episodes of symptomatic nephrolithiasis over the past 2 years, the most recent of which was 5 days ago. She passed a 3-mm stone after several hours of symptoms, and chemical analysis confirm that it was composed of calcium phosphate. Serum studies show sodium of 139 mEq/L, potassium of 3.8 mEq/L, chloride of 106 mEq/L, total CO₂ of 21 mmol/L, BUN of 16 mg/dl, creatinine of 1.1 mg/dl, calcium of 9.3 mg/dl, and phosphorus of 2.8 mg/dl. The urine pH is 6.1. A 24-hour urine collection is significant for hypocitraturia (citrate of 158 mg [target level, >450 mg]). The daily urine ammonium excretion is 32 mmol (reference range = 15–60 mmol/d). A kidney ultrasound shows mild medullary nephrocalcinosis.

Which ONE of the following diagnostic tests is MOST likely to establish the cause of recurrent kidney stone formation in this woman?

- A. Ammonium chloride challenge test
 - B. Fractional excretion of bicarbonate
 - C. Repeat evaluation of urinary parameters in 2 weeks
 - D. Urine osmolal gap
29. A 25-year-old man with a history of type 1 diabetes mellitus is admitted for management of persistent diarrhea and weakness 3 months after undergoing living related kidney transplantation. Admission laboratory studies disclose significant hyperkalemia, with a serum potassium level of 6.5 mEq/L. His medications include insulin aspart, tacrolimus, mycophenolate mofetil, trimethoprim-sulfamethoxazole at 400/80 mg three times weekly, valganciclovir, and metoprolol. On physical examination, he appears fatigued, but he is alert and oriented. The BP is 130/64 mmHg supine and 96/50 mmHg standing. The pulse rate increases from 80/min supine to 110/min standing. The abdominal examination shows normal bowel sounds and no peritoneal signs. The allograft is nontender and does not have a bruit. There is no edema. Laboratory studies show sodium of 142 mEq/L, potassium of 6.5 mEq/L, chloride of 115 mEq/L, total CO₂ of 18 mmol/L, BUN of 40 mg/dl, creatinine of 1.4 mg/dl (increased from 1.2 mg/dl 1 week ago), glucose of 270 mg/dl, creatinine kinase of 31 U/L, leukocyte count of 8000/ μ l, hemoglobin of 9.2 g/dl, and platelet count of 119,000/ μ l. An arterial

blood gas shows pH 7.32, PaCO₂ of 32 mmHg, and bicarbonate of 18 mEq/L. The tacrolimus trough is increased at 12 ng/ml. The urinalysis shows specific gravity of 1.015, 1+ glucose, and no protein, blood, or ketones. An electrocardiogram shows peaked T waves and a prolonged PR interval. A renal transplant ultrasound is normal.

In addition to therapy with intravenous insulin and calcium, which ONE of the following is the next BEST step in the management of this man's hyperkalemia?

- A. Fludrocortisone
 - B. Patiromer
 - C. Isotonic sodium bicarbonate infusion
 - D. Hemodialysis
30. You are asked to evaluate a 66-year-old woman 1 day after admission for management of acute decompensated heart failure for a rising serum creatinine level and persistent hypervolemia. She initially is treated with bumetanide at 3 mg intravenously every 12 hours. Over the initial 24 hours of hospitalization, the urine volume is 3 L. On physical examination, she remains in mild respiratory distress, with a respiratory rate of 24/min. The oxygen saturation is 98% on 2 L/min supplemental oxygen. The BP is 110/60 mmHg, and the pulse rate is 106/min. The jugular venous pressure is 10 cm H₂O. The lung examination shows bibasilar crackles. The estimated sodium output from each dose of bumetanide is estimated to be 140 mEq using a spot urine estimation equation. Laboratory studies show sodium of 132 mEq/L, potassium of 3.8 mEq/L, chloride of 89 mEq/L, total CO₂ of 30 mmol/L, BUN of 52 mg/dl (increased from 40 mg/dl on admission), creatinine of 2.2 mg/dl (increased from 1.9 mg/dl on admission), and glucose of 67 mg/dl. A urinalysis shows specific gravity of 1.012, pH 5.4, no protein, and no blood. The urinary sediment shows many hyaline casts.
- In addition to ongoing close follow-up of this woman's kidney function, which ONE of the following is the MOST appropriate management?**
- A. Begin isolated ultrafiltration
 - B. Redose intravenous bumetanide only after the serum creatinine is \leq 2.0 mg/dl
 - C. Decrease intravenous bumetanide to once daily
 - D. Continue current regimen