

SECTION 9 - RENAL FUNCTION AND HOMEOSTASIS

EXERCISE 9.1 RENAL REGULATION OF FLUID AND ELECTROLYTE BALANCE

Approximate Time for Completion: 2+ hours

Note: If students are chosen for volume loading can provide a control urine sample and volume load 30 minutes before the laboratory starts, then the procedures can be completed in 2 hours.

Introduction

This exercise is designed to introduce students to the kidneys and renal physiology. The kidneys regulate fluid and electrolyte balance under the influence of ADH and aldosterone hormones. In this exercise, students measure the effects of water loading and salt loading on urine concentration, urinary volume, pH, electrolyte composition, and specific gravity. Students often need help calculating electrolyte concentrations in milliequivalents. This exercise could be combined with other exercises from section 9 for a laboratory period on the urinary system.

Materials

1. Urine collection cups, proper urine disposal receptacle
2. Urinometers, droppers
3. pH paper (pH range 3-9), potassium chromate (20 g/dl), silver nitrate 2.9 g/dl)
4. NaCl crystals or salt tablets

Note: Normal and abnormal artificial urine is available (Wards Biology), however, modifications must be made by the instructor to simulate the conditions in this exercise. Also, specific gravity can be measured visually using disposable urine dip strips (Miles Inc., Curtin Matheson Scientific Inc.).

Textbook Correlations: Chapter 17 – Reabsorption of Salt and Water, Renal Control of Electrolyte and Acid-Base Balance

Answers to Questions

1. increase
2. antidiuretic hormone (ADH); posterior pituitary
3. reabsorb water from the nephron
4. aldosterone, from the adrenal cortex
5. angiotensin II
6. specific gravity
7. 5 mEq/L of Ca^{2+}
8. After drinking 500 ml of water, the urine specific gravity should decrease. The increased water intake decreases the plasma osmolality. The osmoreceptors in the hypothalamus sense the increased water concentration and reduces the release of ADH from the posterior pituitary. With less circulating ADH the kidneys do not retain as much water, resulting in the release of excess water in the urine and the lowering of the urine specific gravity.
9.

	<i>Prospector</i>	<i>Partygoer</i>
Urine volume	lower	higher
Specific gravity	higher	lower
Na^+ , Cl^- Content	lower Na^+ and Cl^- , higher K^+	higher Na^+ and Cl^- , lower K^+

The desert prospector probably has a higher secretion of ADH because he is dehydrated than the partygoer. The partygoer has become overly hydrated and has drunk alcohol, which inhibits ADH secretion. The partygoer would therefore excrete a larger volume of more dilute urine than the prospector. This more dilute urine would have a lower specific gravity. Since the prospector is dehydrated and has a smaller circulating

blood volume (and pressure), he should have a higher secretion of aldosterone than the partygoer. In this case, aldosterone would stimulate increased reabsorption of Na^+ and Cl^- , so that less is excreted in the urine, while simultaneously secreting more K^+ into the urine.

10. Drugs that inhibit the reabsorption of Na^+ in the loop of Henle cause an increased urinary excretion of Na^+ and also of Cl^- that follows the Na^+ passively. Further downstream in the distal tubule, aldosterone promotes the rapid reabsorption of the excess Na^+ in exchange for K^+ . Increased excretion of K^+ therefore also occurs as a result of the increased secretion of K^+ into the filtrate by the distal tubule.

EXERCISE 9.2 RENAL PLASMA CLEARANCE OF UREA

Approximate Time for Completion: 1 hour

Introduction

This exercise is designed to introduce students to the concepts underlying the renal plasma clearance of urea. A discussion of filtration, reabsorption, and secretion functions of the kidney should enhance this procedure. In this exercise, students will measure renal plasma clearance rate and use the colorimeter to calculate the urea concentration of samples. This exercise could be combined with other exercises in section 9 for a longer laboratory period on the urinary system.

Materials

1. Urine collection cups, proper urine disposal receptacle
2. Pipettes (capacity 20 μl) with mechanical pipettors (or Repipettes), disposable tips
3. Colorimeter, cuvettes
4. BUN reagents and standard (Stanbio, available through Curtin Matheson Scientific, Inc.)
5. Sterile lancets, 70% alcohol
6. Microhematocrit centrifuge, heparinized capillary tubes, small glass file
7. Proper blood disposal receptacle

Note: Normal and abnormal artificial urine is available (Wards Biology), however, modifications must be made by the instructor to simulate the conditions in this exercise.

Textbook Correlations: Chapter 17 – Renal Plasma Clearance

Answers to Questions

1. inulin
2. urea
3. PAH
4. protein
5. urea
6. inulin
7. creatinine
8. PAH
9. The renal plasma clearance rate (ml/min) of a given compound is the volume (in milliliters) of plasma that originally contained the amount of that compound excreted per minute in the urine. The renal plasma clearance rate is measured by dividing the excretion rate of a compound (mg/min) by the concentration of that compound (mg/ml) in the blood.

10. The GFR measurement is significant because it reflects the net production of filtrate by the nephrons of the kidney. Since urea and other waste products in the plasma are filtered at the glomerulus and excreted in the urine, the efficiency of the kidneys in performing this function can be evaluated. GFR is commonly measured by the clearance of exogenous inulin or by the renal plasma clearance of endogenous creatinine. Inulin (a large polysaccharide) is neither reabsorbed nor secreted by the nephron so its clearance equals the GFR. Creatinine is a normal byproduct of muscle creatine catabolism whose clearance is predictably around 20-25% greater than the true GFR and thus can be conveniently used to estimate this value.
11. If about 30% of substance A is reabsorbed from the filtrate after filtration and returned to the blood, then the renal plasma clearance of A would be less than the glomerular filtration rate measurement (as is true for urea clearance). Substance A must be a molecule that the body wants to retain and works to reabsorb. Substance B, however, is probably a substance that the body wants to eliminate efficiently since it is not only filtered but is secreted into the nephron by 30% above normal filtration. The renal plasma clearance of substance B, therefore is greater than the GFR measurement (as is true for creatinine clearance).
12. An increase in the plasma concentration of urea can occur by the following mechanisms:
 - a. Increased catabolism of proteins liberates increased amounts of amino acids that can be deaminated. Since urea is derived from the released amine groups, an increase in liver urea production follows.
 - b. Decreased blood pressure, as in circulatory shock decreases the glomerular filtration rate (GFR), so that the filtration of urea from plasma is reduced. A drop in the excretion of urea will follow. Consequently, as the production of urea continues without compensatory excretion, the concentration of urea in the blood rises.
 - c. As the kidneys fail, their ability to filter blood at the glomerulus (GFR) decreases and the total urine output begins to fall. Consequently, as the liver production of urea continues without normal renal excretion, the concentration of urea in the blood rises.

EXERCISE 9.3 CLINICAL EXAMINATION OF THE URINE

Approximate Time for Completion: 30 minutes-1 hour

Introduction

This exercise is designed to introduce students to clinical techniques used for both qualitative and microscopic examination of urine samples. Using clinical test strips dipped into urine, students will test for protein, glucose, ketone bodies, hemoglobin, and bilirubin. Using a centrifuge and a microscope, students will also collect and examine urine sediment. Remind the students that the tests they are performing are all tests performed in the clinical laboratory. This exercise could be combined with other exercises from section 9 for a laboratory period on the urinary system.

Materials

1. Microscopes
2. Urine collection cups, test tubes, microscope slides, and coverslips; proper urine disposal receptacle
3. Albustix, Clinitest tablets, Ketostix, Hemastix, Ictotest tablets, or Multistix (all from Ames Laboratories); Ictotest can be obtained from Hardy Diagnostics, Inc.
4. Sediment stain (such as Sternheimer-Malbin stain)
5. Centrifuge, centrifuge tubes
6. Transfer pipettes (droppers)

Textbook Correlations: Chapter 17 – Glomerular Filtration, Reabsorption of Glucose

Answers to Questions

1. (d) protein
2. (c) glucose
3. (a) ketone bodies
4. (b) bilirubin
5. leukocytes, erythrocytes, or epithelial cells
6. large number of casts
7. (a) glomerular nephritis
(b) diabetes mellitus
(c) diabetes mellitus, starvation, carbohydrate deprivation
(d) hemolysis (transfusion reaction), liver disease, or bile duct obstruction
8. Urinary casts are composed of proteins that have precipitated within the renal tubules. Although a small number of casts are found in normal urine, a large number of casts may indicate renal disease. Excess proteins leak through inflamed glomeruli that have become more permeable to proteins as a result of the inflammation.
9. Excess ketone bodies would appear in the urine of a person on a very low carbohydrate weight-reducing diet. Without carbohydrates, the body relies increasingly on the metabolism of fats for energy. Therefore, more triglycerides are hydrolyzed to fatty acids and glycerol. Fatty acids are converted into smaller intermediate compounds known as ketone bodies. The ketone bodies are broken down in aerobic cellular respiration, releasing energy. In this person, however, excess ketone bodies accumulate in the blood (ketonemia) and spill over into the urine (ketonuria.)
10. Yes. The person may have hyperglycemia, but the blood glucose concentration may be below the renal plasma threshold for glucose. In this case, despite the abnormally high levels of plasma glucose, all excess filtered glucose molecules are reabsorbed by the nephrons of the kidney and glucose would not appear in the urine. Hyperglycemia might occur shortly after a normal person eats sugarcoated doughnuts but because all filtered glucose is reabsorbed glycosuria may not be present. In the case of uncontrolled diabetes mellitus however, the lack of insulin results in the inability to transport glucose into tissues. This type of hyperglycemia usually results in very high blood glucose levels that exceed the glucose transport maximum of the kidney tubules. Unable to reabsorb all the glucose flowing in the filtrate, the kidney nephrons of the diabetic eliminates the excess in the urine (glycosuria).
11. If kidney disease results in the abnormal filtration and excretion of plasma proteins in the urine, the concentration of protein in the plasma will be reduced. As a result the colloid osmotic pressure (COP) of the plasma will be decreased. The lowered osmotic pressure in the plasma reduces the normal return of tissue fluid to the blood. The accumulation of tissue fluids results in edema.