Urinary System

LEARNING OBJECTIVES

- Define at least 10 terms relating to the urinary system.
- Describe the two functions of the urinary system.
- Identify four structures of the urinary system.
- Identify the function of at least three structures of the kidney.
- Identify at least five components normally found in urine.
- Describe the possible cause of at least five abnormal components of urine.
- Describe at least three methods used to assess disorders of the urinary system.

KEY TERMS

- **Albuminuria** (al-buh-min-OO-reh-uh) Excess protein in the urine
- **Anuria** (uh-NOO-reh-uh) Complete suppression of excretion by kidneys; absence of urine
- **Dialysis** (dye-AL-ih-sis) Separating particles from a fluid by filtration through a semipermeable membrane
- **Diuresis** (dye-uh-REE-sis) Increased excretion of urine
- **Dysuria** (dye-uh-YOO-reh-uh) Painful or difficult urination
- **Glycosuria** (glee-koh-SOO-reh-uh) Presence of sugar in urine
- **Hematuria** (hem-uh-TOO-reh-uh) Presence of blood in urine
- **Micturition** (mik-uh-TISH-un) Passage of urine; urination
- **Oliguria** (oh-ig-OO-reh-uh) Excretion of diminished amount of urine in relation to fluid intake
- **Polyuria** (pol-ee-YOO-reh-uh) Passage of large amount of urine in given time
- **Pyuria** (pie-ah-YOO-reh-uh) Pus in the urine
- **Urinalysis** (yuhr-ee-nal-ih-sis) Physical, chemical, or microscopic examination of urine
- **Urination** (yuhr-ih-nay-shun) Discharge or passage of urine
- **Void** (voyd) To empty, urinate, or defecate
Structure and Function of the Urinary System

The urinary system has two primary functions:

- To regulate the chemical composition of body fluids
- To remove waste products by forming and excreting urine

The urinary system filters about 180 L of blood plasma daily. On average, 1.0 to 1.5 L of urine is formed and excreted daily to remove waste products. The amount of urine formed is controlled largely by hormones. An increase in the antidiuretic hormone, from the pituitary gland, decreases the amount of water excreted by the kidneys. An increase in the amount of aldosterone, from the adrenal gland, conserves sodium in the plasma, causing water to be retained. The urinary system consists of two kidneys, ureters, the bladder, and the urethra (Fig. 17-1).

Kidneys

The basic structural unit of the urinary system is the kidney. Each kidney is about 4 inches (10 cm) long and 2 inches (5 cm) wide and weighs about 150 g. Each kidney contains about one to two million nephrons, the tiny structures that filter the blood (Fig. 17-2). The nephron is the location of formation of urine and is the functional unit of the urinary system. The process by which the urine is filtered in the nephron is complex (Table 17-1). The kidney has three layers (Fig. 17-3):

- The renal pelvis is the funnel-shaped innermost structure that collects and temporarily stores urine as it is formed.
- Inside the renal pelvis is the hilum, which serves as a passageway for lymph vessels, nerves, the renal artery, and renal vein.

Ureters

The ureters, small tubes composed of smooth muscle tissue, move the urine from the kidney to the bladder.
Urine Formation

Each minute about 600 ml of blood plasma enters the nephrons of each kidney through the renal arteries. In the glomerulus of the nephron, particles are filtered from the blood to be eliminated from the body. Water, glucose, vitamins, amino acids, and chloride salts are reabsorbed into the blood in the renal tubules. Ammonia, potassium, hydrogen ions, and some drugs are secreted into the urine by tubular cells using the process of active transport. The blood leaves the kidneys through the renal veins.

Urine normally consists of 95% water. The remaining 5% includes waste products from the breakdown of protein, hormones, electrolytes, pigments, toxins, and any abnormal components (Table 17-2). Urine is normally sterile in the kidneys and bladder.

Bladder

The bladder, a smooth muscular sac that expands as it fills with urine, can hold up to 1 L. When the bladder fills, nerves in the muscular wall are stimulated and cause the urge to urinate. Urination is also called voiding or micturition.

Urethra

The urethra moves urine from the bladder to be excreted from the body. It is about 1.0 to 1.5 inches (5 cm) long in the female and runs through the vulva. In the male it is 8 inches (20 cm) long and runs through the penis. At the end of the urethra is an opening called the urinary meatus, through which urine passes to the outside of the body.

Assessment Techniques

The primary methods of assessing the urinary system are urinalysis and examinations such as radiography and cystoscopy. Urodynamic testing, another method, measures the force of the urine flow through the system, evaluating the bladder's efficiency.

Urinalysis

Urinalysis is a series of tests that determine urine composition. These tests can detect many body disorders. Urinalysis assesses the urine color, clarity, pH, specific gravity, odor, and volume. It can also determine the components that are not normally found in urine.

Urine color normally varies from yellow to amber or straw. Dark or red urine may indicate the presence of bile or blood. Some drugs may color urine, turning it blue, orange, or other colors.

CASE STUDY 17-1 You are helping a patient use the bedpan and notice that her urine is green. What should you do? Answers to Case Studies are available on the Evolve website: http://evolve.elsevier.com/Gardner

### TABLE 17-2
Characteristics of Urine

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Normal</th>
<th>Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>1.0-1.5 L/day</td>
<td>Polyuria (&gt;2.0 L/day)</td>
</tr>
<tr>
<td>Odor</td>
<td>None</td>
<td>Oliguria (&lt;0.5 L/day)</td>
</tr>
<tr>
<td>Color</td>
<td>Yellow, straw, amber</td>
<td>Sweet (sugar)</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Clear</td>
<td>Ammonia (old)</td>
</tr>
<tr>
<td>pH</td>
<td>4.8-7.4 (average 6)</td>
<td>Offensive (bacteria)</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.002-1.040</td>
<td>Red (blood, infection, some drugs)</td>
</tr>
<tr>
<td>Abnormal Component</td>
<td></td>
<td>Brown (bile)</td>
</tr>
<tr>
<td>Sugar (glycosuria)</td>
<td></td>
<td>Orange, blue (drugs)</td>
</tr>
<tr>
<td>Protein (albuminuria)</td>
<td></td>
<td>Cloudy (pus, bacteria, cells, fat, phosphates)</td>
</tr>
<tr>
<td>Ketones (ketonuria)</td>
<td></td>
<td>Alkaline (phosphates, vegetarian diet)</td>
</tr>
<tr>
<td>Blood (hematuria)</td>
<td></td>
<td>High (dehydration)</td>
</tr>
<tr>
<td>Pus (pyuria)</td>
<td></td>
<td>Low (diuresis)</td>
</tr>
<tr>
<td>Bacteria (bacteriuria)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Possible Cause**

- Diabetes mellitus
- Renal disease
- Incomplete fat metabolism, diabetes mellitus
- Infection, injury
- Infection, injury
- Dead cells, injury
The clarity of urine is normally clear. Cloudy composition may indicate mucus or bacteria in the urine. Alkaline urine contains calcium and may appear cloudy.

The pH of urine should be in the range of 4.8 to 7.4 (average 6.0) or slightly acidic. The acidity helps to prevent bacterial growth. Vegetarian diets may lead to a slightly more alkaline composition. Specific gravity is a measurement of the density of a liquid. The normal specific gravity of urine is 1.002 to 1.040. Dehydration might lead to a higher measurement, and a condition such as diabetes insipidus would lead to a lower specific gravity.

Urine that is fresh should have no odor. An ammonia smell indicates that the specimen is old. A fruity odor may indicate the presence of sugar caused by uncontrolled diabetes mellitus. A foul or putrid smell signifies the presence of bacteria. The normal urine output in 24 hours is 1 to 1.5 L. Anuria, or no urine output, may indicate kidney malfunction or low blood pressure. Oliguria, or less than 0.5 L urine output daily, may be caused by retention of urine or dehydration. Output of more than 2 L is called polyuria. Diuresis, a temporary increase in the amount of urine output, can be caused by ingestion of certain beverages, drugs, or increased fluid intake.

CASE STUDY 17-2 Your friend tells you that she cannot come to your slumber party because she has a runny nose. What should you say?

Answers to Case Studies are available on the Evolve website: http://evolve.elsevier.com/Gerdin

Abnormal components of urine include sugar (glycosuria), proteins such as albumin or globulin (albuminuria), blood (hematuria), pus (pyuria), casts, and ketones. The presence of sugar and waste products of fat metabolism (ketones) may indicate uncontrolled diabetes mellitus. Proteins may appear during pregnancy. Urinary tract contain blood or pus as a result of infection or injury of the urinary system. Casts are dead cells and waste materials that indicate injury to the urinary tract.

Other Examinations

Radiological examination of the kidneys, ureters, and bladder (KUB) may be used to detect the presence of stones in the system. In a procedure called intravenous pyelography (IVP), blockage in the urinary system can be seen. In this procedure, an opaque liquid called a contrast medium is injected into a blood vessel. A series of x-rays is then taken as the liquid passes through the system.

Another procedure used to examine the bladder is called cystoscopy. To view the inside of the bladder and urethra, a cystoscope is inserted in the urethra and the bladder is inflated with water or air. Minor surgical procedures such as taking tissue samples for biopsy are performed with the cystoscope.

Urodynamic tests determine the force of the flow of urine through the system. The rate may be measured with urophonometry. Bladder and sphincter muscle control can be assessed with the use of electromyography.

Brain Byte

Urine therapy, urotherapy, or urinotherapy includes drinking urine and applying it to skin as an alternative medical practice.

Disorders of the Urinary System

Cystitis (cys-TIE-tis) is inflammation of the bladder caused by many different types of bacteria. Cystitis more commonly occurs in women than in men because of the shorter length of the urethra. The leading causative organism is Escherichia coli, or E. coli, which, through poor hygiene, may be carried from the rectum to the urinary tract. The person with cystitis may experience painful urination or dysuria, the urge to urinate frequently, or blood in the urine, known as hematuria. Treatment usually includes an increase in fluid intake and antibiotics. Although cystitis may also be caused by tumors or calculi, many cases can be prevented by using good hygiene practices.

Edema (ed-e-MAY-uh) is an abnormal accumulation of fluid in the tissue intercellular space (Fig. 17-4). This area may be swollen locally in one part of the body or throughout all tissues of the body (systemic). Edema caused by kidney (renal) failure is systemic. It may be treated by use of diuretics and diuretic medication.

Nephritis (neph-NAY-tis), which is inflammation of the kidneys, may occur as a result of illness or chronic cystitis. Pyelonephritis (pih-e-LOH-nef-NAY-tis) is an inflammation of the kidney pelvis and the nephron. Symptoms are similar to those of cystitis but more commonly involve back pain. Untreated nephritis can cause permanent damage to the kidney tissues. Treatment includes antibiotics and increased fluid intake. Renal calculi (REE-nul KAL-kyoo-lay) is a kidney stone. Kidney stones occur in about 1 of 1000 people. Calculi are composed of uric acid and calcium salts. Although the specific cause is not known, a lack of adequate fluid intake and large doses of vitamins, especially vitamin C, may lead to kidney stone formation. The person with a kidney stone feels extreme pain when an area of the kidney or ureter is blocked by the stone. Treatment depends on the location and size of the stone and might include surgical removal. Lithotripsy (LITH-oh-trip-see) has become an alternative treatment.

CASE STUDY 17-3 Your friend tells you that he cannot drink milk because he had once had a kidney stone and does not want to develop another. What should you say?

Answers to Case Studies are available on the Evolve website: http://evolve.elsevier.com/Gerdin

Renal (REE-nul) failure, the absence of urine formation, can be acute or chronic. When the kidneys fail, nitrogen wastes and fluids build up in the tissues, leading to many complications, such as congestive heart failure, and may be fatal. Acute renal failure may result from trauma, toxins, or hemorrhage. It is often treated with restriction of fluids, antibiotics, and diuretic medications. Acute renal failure is often reversible. Chronic renal failure may result from other conditions, such as high blood pressure, diabetes mellitus, and autoimmune disorders. Chronic renal failure develops slowly and may have initial symptoms of sluggishness, fatigue, and mental slowness. The condition is eventually called end-stage renal disease when the kidneys have lost all function. Renal failure results in 80,000 deaths in the United States each year. Treatment includes special diet considerations, diuretic medications, dialysis, and transplantation. In children, chronic renal insufficiency is treated with growth hormone.

Uremia (yoo-REE-mee-uh) is a condition in which the kidneys do not filter the blood. Waste products and waste stay in the blood and tissues, preventing nutrients and oxygen from entering the cells. Uremia may result from trauma, hypotension, nephritis, renal failure, and other conditions. The person suffering from uremia may experience nausea, vomiting, headache, and coma. While crystals, called uremic frost, may form on the skin as the body attempts to excrete the uremic waste. Treatment may include a restricted diet and dialysis to remove the waste products.

Urethritis (you-ree-THREE-tis) is acute or chronic inflammation of the urethra. It may be caused by bacteria or chemical irritation from agents such as bubble bath. The person experiences frequent, painful urination and a red and painful urinary meatus (pee-AY-tus) and surrounding tissues. Urethritis can lead to a narrowing or stricture of the urethra resulting from the formation of scar tissue. Treatment may include antibiotics, sitz baths, and an increase in fluid intake.

Urinary incontinence (in-KON-thee-nee) is the inability to control urination. A number of factors, including lack of muscle control, immobility, or spinal cord or neurologic damage may cause urinary incontinence. Treatment may include retraining the bladder, drugs, or surgery.

Urinary retention is the inability to urinate when the urge is felt or the bladder is full. Retention may result from an obstruction, drugs, trauma, or neurologic disorders. The affected person may experience abdominal pain, distention, and excrcition of small amounts of urine. Treatment focuses on the underlying cause and may include inserting a tube (catheterization) to empty the bladder.

Urinary tract infections, usually caused by bacteria, may affect the bladder, kidneys, or prostate. The person with an urinat tract infection may experience
Issues and Innovations

Dialysis

Dialysis is the filtration of body fluids through a semi-permeable membrane or machine instead of the kidneys to remove excess water and waste. Hemodialysis is the filtration of the blood by using an artificial membrane. Blood is removed from a vein, filtered slowly through the machine, and returned to the body. It may take several hours to complete the process. Hemodialysis may be required two or three times weekly to replace failed kidney function (Fig. 17-5). The procedure is expensive and carries the risk of infection and damage to blood cells. Patients who must use dialysis to treat kidney disease experience many lifestyle changes (Table 17-3).

Another form of dialysis uses the peritoneal membrane of the abdomen as the filter to remove the wastes from body fluid. Continuous abdominal peritoneal dialysis requires insertion of a cannula into the abdominal cavity. A solute of glucose and salts is poured into the abdominal cavity to combine with the waste products. The fluid is then drained out of the cavity by gravity. Peritoneal dialysis can be performed in the home, although a risk of infection exists because of the opening into the body cavity. Other complications include the development of scar tissue called adhesions in the abdomen.

In some cases dialysis may be completed at home. One of five types of home dialysis is continuous ambulatory peritoneal dialysis, which uses the peritoneum to filter wastes and does not use any machinery.

A surgically implanted tube is filled with a dialysate solution that cleans the waste in the peritoneum. The solution is manually put in and removed from the abdomen with this type of home dialysis. Continuous cycling peritoneal dialysis uses the same type of implanted tube and a filtering machine that can be attached at night to remove and instill the dialysate fluid.

Conventional home hemodialysis may be performed at home if the hemodialysis machine and training are available. This is usually performed two or three times a week. Daily home hemodialysis uses the same technique and equipment as conventional home hemodialysis but is performed daily. Nocturnal home hemodialysis uses the same techniques as conventional hemodialysis but is performed at night during sleep.

Kidney Transplant

Kidney transplant is another method of restoring kidney function. Drawbacks include the difficulty of matching tissues, expense, and shortage of donor kidneys. Although the cost of kidney transplant is high, this cost is still less than the cost of treating a patient with kidney failure by using dialysis over a period of 3 years (Table 17-4). Kidney dialysis costs about $66,000 annually. The donor program pays the cost of donation of organs for transplant.

TABLE 17-3
Lifestyle Changes of Dialysis*

<table>
<thead>
<tr>
<th>Area</th>
<th>Change</th>
<th>Possible Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood count</td>
<td>Anemia, trouble sleeping</td>
<td>Plan activities for peak energy, limit fluids, rest periods, light exercise regularly, avoid heavy lifting</td>
</tr>
<tr>
<td>Emotion</td>
<td>Feeling &quot;blair&quot; before dialysis and &quot;wrung out&quot; after</td>
<td>Adjust activities to days when feeling good</td>
</tr>
<tr>
<td>Fluid retention</td>
<td>Weight gain, high blood pressure, headache, leg cramps</td>
<td>Adjust diet and restrict fluid intake to gain less than 2 lb daily</td>
</tr>
<tr>
<td>Mouth</td>
<td>Dry mouth, bad breath</td>
<td>Rinse mouth, chew gum, suck sugar-free candy</td>
</tr>
<tr>
<td>Skin</td>
<td>Dry skin, brittle hair, itching, bruising, sunburn more easily</td>
<td>Mild soap, shampoo, lotion, diet change, medication for itching, protective clothing</td>
</tr>
</tbody>
</table>

*Changes may or may not occur because people do not all react the same way to treatment.

TABLE 17-4
Estimated U.S. Average 2008 Cost of Transplants*

<table>
<thead>
<tr>
<th>Organ</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>$787,700</td>
</tr>
<tr>
<td>Single lung</td>
<td>$450,400</td>
</tr>
<tr>
<td>Double lung</td>
<td>$657,800</td>
</tr>
<tr>
<td>Heart-lung</td>
<td>$1,235,800</td>
</tr>
<tr>
<td>Liver</td>
<td>$523,400</td>
</tr>
<tr>
<td>Kidney</td>
<td>$259,000</td>
</tr>
<tr>
<td>Pancreas</td>
<td>$275,200</td>
</tr>
<tr>
<td>Intestine</td>
<td>$1,121,800</td>
</tr>
</tbody>
</table>

*This estimated cost of transplant includes medical and non-medical items. These are divided into categories including pre-transplant, procurement, hospital, physician, posttransplant and immunosuppression. From United Network for Organ Sharing (UNOS), http://transplantliving.org.

Many factors are used to determine who receives a kidney when it becomes available. The length of time the recipient has been on the waiting list, blood type, tissue type, and medical condition are considered. Geographic location is also a determining factor in the selection of the candidate. Local waiting lists at hospitals and a national list exist. The United Network for Organ Sharing (UNOS) maintains the national list. Kidney transplantation is now routine and has a success rate of 94% from cadaver donors and 98% from living donors. According to the National Kidney Foundation (NKF), 4,675 kidney patients, 1,506 liver patients, 371 heart patients, and 234 lung patients died in 2008 while waiting for organ transplants. The shortage of donors, both living and cadaver, is a concern for health professionals. As of 2010, the NKF reported that 194,748 patients were waiting for transplant organs.

Kidneys are one of 22 organs that are being regrown by the Wake Forest Institute for Regenerative Medicine in North Carolina. In this regenerative medicine process, cells are taken from the patient's body, cultivated in Petri dishes, and layered into three-dimensional models of the organ. This procedure has been used successfully to create bladders.

Lithotripsy

Extracorporeal shock wave lithotripsy uses high-energy pressure or sound waves sent through the kidney to break apart and disintegrate kidney stones. The "shock wave" may be sent through water or air. Two types of shock wave therapy are available. The original method sent the shock waves through water. The patient was placed in a tub of water for this technique. A newer procedure passes the shock waves through padded cushions on a table. In this method the patient is not placed in water. With both techniques, two fluoroscopic or ultrasound monitors are used to position the lithotripsy machine in order to target the stone precisely. Up to 2000 "shocks" may be necessary to disintegrate a stone. Although the procedure may occasionally cause bleeding or heart irregularities, it may prevent the need for surgery to remove the stone (Fig. 17-6). Another procedure, called tunnel surgery, may be used when lithotripsy is not recommended. In this method a small incision is made into the kidney from the back. A tube is then inserted in the kidney to remove the stones.
2. Describe the function of the four structures of the urinary system.
3. Describe the function of the structures of the kidney.
4. Describe the location and function of each of the following parts of the urinary system: bladder, renal pelvis, cortex, and ureter.
5. List five components normally found in urine.
6. List five abnormal components of urine and one possible cause of each.
7. Differentiate between peritoneal dialysis and hemodialysis.
8. Describe three methods of assessment of the urinary system.
9. Use the following terms in one or more sentences that correctly relate their meaning: diuresis, glycosuria, polyuria, and urination.

Critical Thinking
1. Investigate and compare the cost of at least three tests used in diagnosing disorders of the urinary system.
2. Investigate the function of at least five common medications used in treatment of the urinary system.
3. List at least five occupations involved in the health care of urinary system.
4. Investigate the recommended dietary needs after renal failure.
5. Investigate and compare the cost of dialysis and kidney transplant. What other factors might be considered in choosing the method of treatment for renal failure?
6. List five beverages that act as diuretics.
7. Investigate the function of each part of the nephron.
8. Use the Internet to research recent developments or treatment methods relating to the urinary system.
9. Use the Internet to research and compare the possible types of dialysis.
10. Use the Internet to research sports drinks and water intoxication.

Explore the Web

Dialysis
Medline

National Kidney and Urologic Diseases Information Clearinghouse (NKUDIC)

Sports Drinks
About.com
http://sportmedicine.about.com/od/hydrationandflusht/h/hypoxaemia.htm

HowStuffWorks.com
http://health.howstuffworks.com/water-intoxication.htm

Summary
- The functions of the urinary system include regulating the composition of body fluids and removing wastes by filtering the blood.
- Structures of the urinary system include the kidneys, ureters, bladder, and urethra.
- Structures of the kidney include glomerulus, Bowman's capsule, loop of Henle, and collecting duct.
- Components normally found in urine include water, yellow coloring, and a pH of about 6.

Review Questions
1. Describe the two functions of the urinary system.