to reverse sepsis. Therefore, declines in urine volume, especially in the intensive care unit, should lead to a diligent search for a focus of infection.

Urinary tract obstruction is often a reversible cause of renal injury and therefore important to diagnose. Although urine output is frequently reduced with obstruction, partial obstruction may be associated with an increase in urine output. Renal ultrasound is useful to diagnose hydronephrosis; urinalysis may reveal hematuria, infection, or may be bland. Left untreated renal atrophy may ensue.

In many ways, the severity of injury is best assessed at the bedside. Oliguric renal failure (100-400 mL urine/24 hr) or anuric renal failure (<100 mL urine/24 hr) has a worse prognosis than non-oliguric renal failure (>400 mL urine/24 hr). A low fractional excretion of sodium or, if the patient is taking diuretics, a low fractional excretion of urea may suggest volume depletion as the likely cause. Fractional excretion of any substance is simply calculated as the ratio of the clearance of the analyte in question to the clearance of creatinine. However, a low fractional excretion of urea or sodium may have causes other than volume depletion. For example, because of the heterogeneous nature of nephronal injury, contrast-induced injury, sepsis, or burns often result in a low fractional excretion of sodium despite intrinsic renal failure.

Intrinsic renal injury can be detected by examining the urine sediment. The classic manifestation of acute tubular necrosis (ATN) is the presence of dirty-brown granular casts. However, in severe AKI, there may be a large amount of amorphous granular material without cast formation (see Figs. 26-3 and 26-5). This occurs because severe AKI may result in failure to produce the Tamm-Horsfall protein, leading to no formation of casts. In the absence of dirty-brown granular casts, a diagnosis of acute tubular injury can still be made based on the presence of dysmorphic epithelial cells in the urine. These epithelial cells, under hypoxic conditions, transform from the round, fried-egg appearance of the tubular cell to angular cells taking the shape of triangles or teardrops (see Fig. 26-3). A normal sediment, on the other hand, suggests minimal or no kidney injury.

The severity of injury needs to be assessed, as well as its relationship to the preexisting state of kidney health. Severe injury is required for AKI to be manifested when the kidney is otherwise healthy. Little damage is needed to produce a severe injury if CKD preexists. More important, however, is the response to injury. It remains unclear why do certain individuals have low GFR and others with the same extent of injury do not, but this reflects the protective nature of responses that can result in poor or better GFR.

End-organ manifestations of AKI include pulmonary edema or acute respiratory distress syndrome; uremic encephalopathy as alteration of mental status or asterixis; and uremic pericarditis or pleuritis manifested as pericardial or pleural friction rub. Although pulmonary edema is still a common manifestation of uremia, uremic serositis and encephalopathy are now rare.

The individual elements that can be seen in the urine and may be of diagnostic importance are as follows: dysmorphic RBCs, sterile pyuria manifested by white blood cells (WBCs) in the urine without bacteria, urinary tract infection characterized by both WBCs and bacteria in the urine, dysmorphic tubular cells suggesting ATN, intact renal tubular cells suggesting recovery from AKI, bubble cells, glitter cells, and oval fat bodies (see Figs. 26-2 and 26-3).

Budding yeast in a patient with diabetes may suggest the need to remove a long-standing indwelling catheter. Uric acid crystals in large amount suggest tumor lysis syndrome; calcium oxalate crystals may suggest ethylene glycol poisoning; and magnesium ammonium phosphate (triple phosphate) crystals may suggest infection with urease-positive organisms (see Fig. 26-4).

Casts can occur in various forms, such as RBC, WBC, epithelial cell, granular, hyaline, and dirty-brown granular casts. They can also occur in various shapes, such as broad and narrow casts. Examples of these are demonstrated in Figure 26-5.

For a deeper discussion on this topic, see Chapter 114, "Approach to the Patient with Renal Disease," in Goldman-Cecil Medicine, *25th Edition.*

SUGGESTED READINGS

Agarwal R: Developing a self-administered CKD symptom assessment instrument, Nephrol Dial Transplant 25:160–166, 2010.

Earley A, Miskulin D, Lamb EJ, et al: Estimating equations for glomerular filtration rate in the era of creatinine standardization: a systemic review, Ann Intern Med 156:785–795, 2012.

Gansevoort RT, Matsushita K, van der Velde M, et al: Lower estimated GFR and higher albuminuria are associated with adverse kidney outcomes: a collaborative meta-analysis of general and high-risk population cohorts, Kidney Int 80:93–104, 2011.

Maroni BJ, Steinman TI, Mitch WE: A method for estimating nitrogen intake of patients with chronic renal failure, Kidney Int 27:58–65, 1985.

Perrone RD, Madias NE, Levey AS: Serum creatinine as an index of renal function: new insights into old concepts, Clin Chem 38:1933–1953, 1992.

Pickering TG, Miller NH, Ogedegbe G, et al: Call to action on use and reimbursement for home blood pressure monitoring: a joint scientific statement from the American Heart Association, American Society Of Hypertension, and Preventive Cardiovascular Nurses Association, Hypertension 52:10–29, 2008.

Pickering TG, Shimbo D, Haas D: Ambulatory blood-pressure monitoring, N Engl J Med 354:2368–2374, 2006.

Perazella M, Coca S, Kanbay M, et al: Diagnostic value of urine microscopy for differential diagnosis of acute kidney injury in hospitalized patients, Clin J Am Soc Nephrol 3:1615–1619, 2008.