creatinine may rise disproportionally more than urea, for example in advanced cirrhosis, low-protein diets, or states associated with the use of cationic transport inhibitors (e.g., cimetidine).

For many decades, the assessment of creatinine clearance by a 24-hour urine collection has been the mainstay of assessing renal function. However, given that creatinine may be secreted (and not just filtered), this test may overestimate GFR. Furthermore, voiding outside the collection jug is common and may lead to errors in estimating GFR. Although a 24-hour urine collection is not routinely recommended to assess renal function, it may still be useful for estimating GFR in sarcopenic individuals and in those with advanced liver disease. Creatinine clearance can be easily calculated as the urinary flow rate (in mL/min) times the ratio of urinary creatinine to plasma creatinine. A timed collection is needed. Creatinine excretion approximates 15 mg/kg/day. Although this rate is variable (the coefficient of variation from day to day over 28 days on a standard diet varies from 6% to 22%) and depends on meat intake, it can be used to estimate whether urine has been grossly undercollected or overcollected.

Usually, GFR is estimated through the use of equations that account for age in years, race, sex, and serum creatinine. The Modification of Diet in Renal Disease (MDRD) equation uses a creatinine measurement (Scr) that has been calibrated to an isotope dilution mass spectrometry standard:

$$\text{GFR}\,[\text{in mL/min/1.73 m}^2] = 175 \times (\text{Scr})^{-1.154} \times (\text{Age})^{-0.203} \times 0.742\,[\text{if female}] \times 1.212\,[\text{if black}]$$

A newer equation, called the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation, is less likely to estimate GFR as low if the GFR is higher than 60 mL/min/1.73 m^2. This equation is more complicated:

$$\text{GFR}\,[60\ \text{mL/min/1.73 m}^2] = 141 \times \mathit{min}(\text{Scr}/\kappa,1)^{\alpha} \times \mathit{max}(\text{Scr}/\kappa,1)^{-1.209} \times 0.993^{\text{Age}} \times 1.018\,[\text{if female}] \times 1.159\,[\text{if black}]$$

where Scr is serum creatinine (in mg/dL), κ is 0.7 for females and 0.9 for males, α is −0.329 for females and −0.411 for males, *min* indicates the minimum of Scr/κ or 1, and *max* indicates the maximum of Scr/κ or 1. Several calculators to estimate GFR using the CKD-EPI equation or the MDRD equation are available on the World Wide Web or as applications for personal devices.

Assessment of Albuminuria

The assessment of albuminuria is fundamental because it may point to the cause of the CKD. Furthermore, greater albuminuria is associated with an accelerated progression of CKD and cardiovascular disease. As a result, albuminuria is now used to stage CKD (see Fig. 26-1).

Albumin excretion rate is normally less than 10 mg/24 hr, and an excretion rate of 30 mg/24 hr or higher is considered abnormal and moderately increased. An albumin excretion rate of 300 mg/24 hr or higher is considered severely increased. Albuminuria can be more conveniently assessed by measuring the ratio of urine albumin and urine creatinine concentrations in a spontaneously voided specimen. Given that the creatinine excretion rate averages 1 g/day, an albumin-to-creatinine ratio of 30 mg/g creatinine or higher is considered abnormal and moderately increased; a ratio of 300 mg/g creatinine is considered severely increased.

An albumin excretion rate higher than 2200 mg/24 hr (corresponding to 3000 mg protein/24 hr) is considered nephrotic. Such a degree of albuminuria/proteinuria is often accompanied by edema, hypoalbuminemia, and hyperlipidemia. The combination of these disorders is referred to as the *nephrotic syndrome*, and the severe proteinuria reflects a profound disorder of glomerular permselectivity. Common causes of nephrotic syndrome in adults are diabetic nephropathy, focal segmental glomerulosclerosis, membranous nephropathy, and amyloidosis. Among children, minimal change nephropathy and focal segmental glomerulosclerosis are important causes of nephrotic syndrome.

Assessment of Blood Pressure

Hypertension is a common accompaniment of CKD, yet the evaluation of hypertension often is performed poorly. Current management of hypertension is directed most often to management of blood pressure measurements obtained during clinic visits. However, blood pressure may be falsely higher in the clinic (*white coat hypertension*) or lower in the clinic (*masked hypertension*) compared with 24-hour ambulatory blood pressure measurements. The latter technique is mostly limited to research or to management in a few difficult cases. However, home blood pressure recordings self-measured by the patient twice daily for about 1 week every month can help diagnose and manage hypertension more effectively. Self-performance of these measurements may promote adoption of a healthier diet and better medication adherence by the patient, as well as reducing therapeutic inertia on the part of the physician.

Assessment of Dietary Sodium Intake

At steady state, when body weight is neither increasing nor decreasing, the dietary sodium intake can be judged by 24-hour urine collection. To establish adequacy of urine collection, the measurement of urine creatinine in 24-hour urine sample is important. The creatinine excretion rate in an adequately collected specimen should approach 1 g/day for women and 1.5 g/day for men. Dietary potassium and protein intake can be monitored similarly. Measurement of urine urea nitrogen in the 24-hour urine sample can reveal the adequacy of dietary protein intake. Dietary sodium restriction can improve blood pressure, can enhance the biologic actions of inhibitors of the renin-angiotensin system, and may protect the heart, blood vessels, and kidneys independent of improvement in blood pressure.

Microscopic Urinalysis

Microscopic urinalysis at initial evaluation and on an ongoing basis can reveal vital information about the health of the kidney. Evaluation should be performed by centrifugation of at least 12 mL of a freshly voided specimen. Cells, casts, crystals, and other elements can corroborate the diagnosis of the cause of CKD. Examples are shown in Figures 26-2 through 26-5.

Renal Imaging

Bladder ultrasonography is a tool that can be used to assess residual urine volume. The wide availability of this tool allows