# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summary</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Basics</strong></td>
<td>4</td>
</tr>
<tr>
<td>Definition</td>
<td>4</td>
</tr>
<tr>
<td>Epidemiology</td>
<td>4</td>
</tr>
<tr>
<td>Etiology</td>
<td>4</td>
</tr>
<tr>
<td>Pathophysiology</td>
<td>4</td>
</tr>
<tr>
<td>Classification</td>
<td>5</td>
</tr>
<tr>
<td><strong>Prevention</strong></td>
<td>6</td>
</tr>
<tr>
<td>Primary prevention</td>
<td>6</td>
</tr>
<tr>
<td>Screening</td>
<td>6</td>
</tr>
<tr>
<td>Secondary prevention</td>
<td>6</td>
</tr>
<tr>
<td><strong>Diagnosis</strong></td>
<td>7</td>
</tr>
<tr>
<td>Case history</td>
<td>7</td>
</tr>
<tr>
<td>Step-by-step diagnostic approach</td>
<td>7</td>
</tr>
<tr>
<td>Risk factors</td>
<td>8</td>
</tr>
<tr>
<td>History &amp; examination factors</td>
<td>10</td>
</tr>
<tr>
<td>Diagnostic tests</td>
<td>12</td>
</tr>
<tr>
<td>Differential diagnosis</td>
<td>14</td>
</tr>
<tr>
<td>Diagnostic criteria</td>
<td>16</td>
</tr>
<tr>
<td><strong>Treatment</strong></td>
<td>17</td>
</tr>
<tr>
<td>Step-by-step treatment approach</td>
<td>17</td>
</tr>
<tr>
<td>Treatment details overview</td>
<td>22</td>
</tr>
<tr>
<td>Treatment options</td>
<td>25</td>
</tr>
<tr>
<td>Emerging</td>
<td>54</td>
</tr>
<tr>
<td><strong>Follow up</strong></td>
<td>55</td>
</tr>
<tr>
<td>Recommendations</td>
<td>55</td>
</tr>
<tr>
<td>Complications</td>
<td>56</td>
</tr>
<tr>
<td>Prognosis</td>
<td>57</td>
</tr>
<tr>
<td><strong>Guidelines</strong></td>
<td>58</td>
</tr>
<tr>
<td>Diagnostic guidelines</td>
<td>58</td>
</tr>
<tr>
<td>Treatment guidelines</td>
<td>59</td>
</tr>
<tr>
<td><strong>Evidence tables</strong></td>
<td>60</td>
</tr>
<tr>
<td>References</td>
<td>63</td>
</tr>
<tr>
<td>Disclaimer</td>
<td>78</td>
</tr>
<tr>
<td>Summary</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>◊ Chronic kidney disease (CKD) is a common condition that is often unrecognized until the most advanced stages.</td>
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<td>◊ Diagnosis is determined only by laboratory studies: proteinuria or hematuria, and/or a reduction in the glomerular filtration rate, for more than 3 months’ duration.</td>
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<td>◊ The most common causes are diabetes mellitus and hypertension.</td>
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<td>◊ Glycemic control for diabetic kidney disease and optimization of blood pressure are key in slowing the progression of disease.</td>
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<tr>
<td>◊ CKD is a risk factor for cardiovascular disease, independent of comorbidities such as diabetes, hypertension, and dyslipidemia.</td>
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Chronic kidney disease

Definition

Chronic kidney disease (CKD), also known as chronic renal failure, is defined as abnormalities of kidney structure or function, present for ≥3 months, with implications for health.[1] This means a glomerular filtration rate less than 60 mL/minute/1.73 m², or the presence of one or more of the following markers of kidney damage: albuminuria/proteinuria, urine sediment abnormalities (e.g., hematuria), electrolyte abnormalities due to tubular disorders, abnormalities detected by histology, structural abnormalities detected by imaging, or history of kidney transplantation.[1]

Epidemiology

This is a common condition that is often unrecognized until the most advanced stages. It is estimated that 9% to 13% of the adult population worldwide has CKD.[3] In 2017, the estimated worldwide prevalence of CKD stages 1 to 2 accounted for 5%, stage 3 for 3.9%, stage 4 for 0.16%, stage 5 for 0.07%, dialysis for 0.041%, and kidney transplantation for 0.011%. Prevalence in the US adult population is 13%. The incidence is rising and is thought to be due to an aging population; a higher incidence of diseases such as diabetes and hypertension, which are the most common causes in the adult population; and an increased incidence of glomerular disorders such as focal segmental glomerulosclerosis. Black people, Hispanic people, and those with a family member who has a diagnosis of kidney disease have a higher prevalence than the general population. Additionally, individuals with an episode of acute kidney injury are most likely to be at risk for chronic kidney injury and end-stage kidney disease in the future.[10]

Etiology

The most common cause in the adult population is diabetes.[7] It is estimated that one third of patients with diabetes will develop kidney disease, as defined by albuminuria and/or a reduction in the glomerular filtration rate within 15 years after the diagnosis of diabetes.[11] [12] Hypertension is the second most common cause.[7] The interaction between hypertension and CKD is complex, with hypertension a cause and a consequence of CKD.[13] Often people are given the diagnosis of hypertensive renal disease if no other identifiable etiology is evident. Less frequent causes include cystic disorders of the kidney (polycystic kidney disease), obstructive uropathy, glomerular nephrotic and nephritic syndromes such as focal segmental glomerulosclerosis, membranous nephropathy, lupus nephritis, amyloidosis, and rapidly progressive glomerulonephritis.[14]

Pathophysiology

The pathophysiology is complex. Regardless of the method of renal injury (i.e., diabetes, hypertension, or glomerular disorders), once renal damage has occurred, a cascade of events ensues.[15] [16]

• In response to renal injury, there is thought to be an increase in intraglomerular pressure with glomerular hypertrophy, as the kidney attempts to adapt to nephron loss to maintain constant glomerular filtration.
• An increase in glomerular permeability to macromolecules such as transforming growth factor-beta (TGF-beta), fatty acids, proinflammatory markers of oxidant stress, and protein may result in toxicity.
Chronic kidney disease

Basics

to the mesangial matrix, causing mesangial cell expansion, inflammation, fibrosis, and glomerular
scarring.
• Additionally, renal injury results in an increase in angiotensin II production, causing an upregulation
of TGF-beta, contributing to collagen synthesis and renal scarring within the glomerulus.
• Both the structural alterations and accompanying biochemical, cellular, and molecular changes seem
to account for progressive renal scarring and loss of kidney function.
• All forms of CKD are also associated with tubulointerstitial disease; the exact mechanism of injury is
not known but is thought to be secondary to a reduction in blood supply in addition to an infiltration
of lymphocytes and inflammatory mediators that result in interstitial fibrosis and tubular atrophy.

Classification

Kidney Disease: Improving Global Outcomes (KDIGO)
classification[1]

KDIGO classifies CKD based on cause (C), glomerular filtration rate category (G), and albuminuria category
(A).

• Cause is ascertained from history (e.g., diabetic kidney disease, hypertensive nephrosclerosis).

• Glomerular filtration rate (GFR) category is based on GFR (mL/minute/1.73 m²):
  • G1 GFR ≥90: normal or high
  • G2 GFR 60 to 89: mildly decreased
  • G3a GFR 45 to 59: mildly to moderately decreased
  • G3b GFR 30 to 44: moderately to severely decreased
  • G4 GFR 15 to 29: severely decreased
  • G5 GFR <15: kidney failure.

• Albuminuria category is based on albumin excretion rate (AER) or albumin to creatinine ratio (ACR):
  • A1 AER <30 mg albumin/24 hours or ACR <30 mg/g: normal to mildly increased
  • A2 AER 30 to 300 mg albumin/24 hours or ACR of 30 to 300 mg/g: moderately increased
  • A3 AER >300 mg albumin/24 hours or ACR >300 mg/g: severely increased.

There is substantial existing literature using the term microalbuminuria; however, the KDIGO work group
encourages adoption of the term ‘albuminuria’, with subsequent quantification of the level or amount.[1]

A urine ACR >2200 mg/g may be accompanied by signs and symptoms of nephrotic syndrome (e.g., low
serum albumin, edema, and high serum cholesterol).[1]

However, nephrotic level proteinuria is conventionally defined as >3.5 g proteinuria per 24 hours.[2]
Primary prevention

The evidence for the prevention of CKD is lacking as compared with large scale randomized trials for cardiovascular disease. Most trials have focused on modifiable diseases and risk factors that have been associated with CKD, namely diabetes and hypertension. Clinical evidence supports the recommendation for a goal HbA1c <7%, blood pressure target of <140/90 mmHg, tobacco cessation, and ideal body weight with BMI <27 to prevent the development of CKD. Due to the lack of widespread screening guidelines with serum creatinine or urinary albumin, often patients are diagnosed after CKD has developed.[36]

Screening

There are no established screening guidelines for the general population for CKD. However, based on expert opinion, there are recommendations to screen those considered high-risk and include all individuals with diabetes and hypertension age <50 years, and all of those age >50 years, with an annual urinalysis and serum creatinine. Other high-risk populations, such as those with a family history of kidney disease, should also be considered in the screening program.[48]

Patients with risk factors for CKD such as diabetes, hypertension, or a family member with CKD should be evaluated annually with serum creatinine and mathematical formulation for estimation of the glomerular filtration rate (GFR) in addition to urinalysis for hematuria and/or proteinuria.

Secondary prevention

Underlying risk factors associated with disease states should be treated, including optimization of glycemic control in diabetes and achievement of the goal blood pressure of <140/90 mmHg with ACE inhibitors or angiotensin-II receptor antagonists. Consideration can be given to a lower blood pressure goal in those with proteinuria of >500 mg per 24 hours.[68] [137] [69] [72] Although data are limited in the CKD population as compared with the general population, tobacco cessation, weight loss, salt restriction, and optimal lipid management with statin therapy are indicated. Moderate protein restriction is recommended in late stage (GFR category G4 or G5) disease, as a management strategy to control uremia in order to delay the initiation of dialysis.[110] Severe protein restriction may result in malnourishment and poorer outcomes. Aspirin use has also been beneficial for cardioprotection in those with CKD, although there is a higher risk for minor bleeding than in the general population.
Case history

Case history #1

A 54-year-old man with a 10-year history of diabetes and hypertension, with complications of diabetic retinopathy and peripheral neuropathy, presents to his primary care physician with complaints of fatigue and weight gain of 4.5 kg over the past 3 months. He denies any changes in his diet or glycemic control, but does state that he has some intermittent nausea and anorexia. He states that he has noticed that his legs are more swollen at the end of the day but improve with elevation and rest. Physical exam reveals an obese man with a sitting blood pressure of 158/92 mmHg. The only pertinent physical exam findings are cotton wool patches and microaneurysms bilaterally on fundoscopic exam and pitting, bilateral lower-extremity edema.

Other presentations

The disease presents insidiously over months with vague complaints of fatigue, mild reduction in appetite, and, at more advanced stages, nausea and anorexia. Edema is a common presentation - as the glomerular filtration rate declines, there is an inability to effectively excrete salt and water to remain in metabolic balance with dietary intake. Additionally, proteinuria with a decrease in serum albumin may contribute to the development of peripheral edema.[3]

Step-by-step diagnostic approach

It is important to note that a significant proportion of people are asymptomatic, and the diagnosis relies on pathologic evidence of kidney damage such as hematuria and/or proteinuria, or laboratory evidence of a reduction in the glomerular filtration rate (GFR) with an elevated serum creatinine.

History

Signs and symptoms are often vague, including fatigue (which may be related to uremia or the anemia associated with CKD), nausea, and possibly the development of edema. Uremic illness is due largely to the accumulation of organic waste products that are normally cleared by the kidneys, and symptoms may be present to some degree in the early stages of kidney failure.[37] As kidney failure progresses to the more advanced stages of uremia, patients will often describe anorexia, nausea, vomiting, restless legs, pruritus, and overall not feeling well.[38] If patients begin to have a lack of urine production, then the resulting fluid overload may be present with dyspnea and orthopnea due to pulmonary edema. Cognition may be affected in all stages of CKD.[3] In the most advanced stages of uremia, patients may present with seizures or coma.[39]

Examination

Signs as a consequence of CKD are hypertension, peripheral edema (due to sodium retention and exacerbated by hypoalbuminuria), and pallor due to anemia.[3] Physical exam findings are also directed toward the discovery of end-organ damage associated with causative disease states such as diabetes or hypertension, which cause CKD. A fundoscopic eye exam is critical for the diagnosis of diabetic or hypertensive retinopathy as evidence of microvascular damage that has likely occurred in the kidney, resulting in CKD. In men, a rectal exam for prostatic enlargement or for the diagnosis of prostate
Chronic kidney disease

nODULES can be helpful in determining a diagnosis of obstructive uropathy. In glomerular nephrotic and nephritic syndromes, the signs and symptoms of CKD may present more acutely with accelerated hypertension, periorbital and peripheral edema, rashes, or arthritis on musculoskeletal exam for patients with autoimmune disorders.[40] Patients may describe their urine as foamy if significant proteinuria is present, or tea- or cola-colored in the setting of hematuria.

**Initial investigations**

Most people are unaware that they have CKD and are informed only after abnormalities are discovered by blood and/or urine tests.[3] The first diagnostic tests to order are a serum creatinine (as part of renal chemistry), estimated GFR (with consideration of serum cystatin-C in people with extremes of muscle mass), and urinalysis to assess for hematuria and proteinuria.[1] [3] For the diagnosis of CKD, urinary albumin assessment is usually preferred to that of total urine protein with calculation of the albumin excretion rate or the albumin to creatinine ratio.[1] However, nephrotic level proteinuria is conventionally defined as $>3.5 \text{ g proteinuria per 24 hours}$.\[^2\]

Proteinuria is both a diagnostic and a prognostic variable in the evaluation of patients with CKD.[3] [41]

Renal ultrasound is required to evaluate kidney size, mass lesions, urinary tract obstruction, and, with a duplex examination, renal arterial flow.[3]

**Additional investigations**

Kidney biopsies are performed in the minority of patients with CKD.[1] A kidney biopsy to determine a pathologic diagnosis is indicated if a glomerular nephrotic or nephritic syndrome is suspected, or in people with diabetes with atypical presentations such as rapidly progressive kidney failure. Nephrotic syndrome may be suggested by proteinuria, and both nephritic and nephrotic syndromes may be suggested by severe presenting symptoms (accelerated hypertension, periorbital and peripheral edema) or with symptoms of underlying autoimmune diseases (rashes or arthritis). Certain infections, such as hepatitis B and C, syphilis, and streptococcal pharyngitis are associated with glomerular disorders. A kidney biopsy is essential in these cases to determine the pathologic lesion.

Imaging of the genitourinary tract may be helpful in the evaluation of a patient with CKD. A plain abdominal x-ray is a nonspecific test that may aid in the detection of calcium-containing kidney stones. Other radiologic tests, such as an abdominal computed tomography, are reserved for evaluation of stone disease and further characterization of renal cystic or mass lesions. Magnetic resonance imaging is reserved for renal mass lesions such as renal cell carcinoma.

**Risk factors**

**Strong diabetes mellitus**

- This is the most common cause.[7]
- It is estimated that approximately 20% to 40% of people with diabetes will have CKD, as documented by albuminuria and/or a reduction in the glomerular filtration rate, within 15 years of diagnosis.[11] [12]
- CKD rarely develops in patients with type 1 diabetes before 10 years following diagnosis, whereas CKD is present at time of diagnosis in around 3% of patients with type 2 diabetes.[12]
• Glycemic control directly correlates with the development of diabetic nephropathy and the rapidity of progression to end-stage renal disease.[11]
• Hyperglycemia results in formation of advanced glycosylated end products. This leads to mesangial oxidative stress, which results in matrix expansion and increased vascular permeability, which in turn attracts inflammatory mediators.[17] These promote collagen production, leading to glomerular sclerosis.[18]

hypertension
• This is the second most common cause of CKD.[7]
• Hypertension is also a consequence of CKD (including from other causes such as diabetic kidney disease, and glomerular nephrotic and nephritic syndrome), and contributes to its progression to end-stage renal disease.[13]
• Hypertension is thought to affect both the vasculature and tubulointerstitial components of the kidney, resulting in ischemic damage from arterial narrowing. The end result is loss of nephron mass, and atrophy and fibrosis of the tubules and interstitium.

age >50 years
• Older age is a key predictor of CKD. Healthy aging is associated with structural changes in the kidney and a decrease in glomerular filtration rate (GFR).[19] Typically the GFR declines by 0.75 mL/minute/1.73 m² per year in healthy aging, but urine albumin excretion does not change, thus, the increase in the prevalence of criteria-defined CKD in healthy older adults is due more to a GFR decline than to increasing albuminuria and has a much lower risk of progression to end-stage renal disease.[19] However, increasing age is associated with an increased likelihood of comorbid conditions that are risk factors for CKD, such as diabetes, hypertension, and cardiovascular disease.[20]

childhood kidney disease
• A history of childhood kidney disease is a risk factor for adult CKD and end-stage renal disease (ESRD). Children with a medical history of congenital anomalies, glomerular disease, or pyelonephritis with normal kidney function and blood pressure have a four-fold increased risk for ESRD as compared to children without kidney disease.[21]

Weak smoking
• Smoking has been associated as a risk factor for the development and progression of the disease, likely because of accelerated atherosclerosis and vascular disease, as well as exacerbating underlying hypertension.[22]

obesity
• Obesity is an associated risk factor.[23] It may contribute to the development of diabetes, exacerbate poor control of hypertension, contribute to renal ischemia and hypertension with associated sleep apnea, and cause glomerular strain with hypertrophy and glomerulosclerosis.[24]

black or Hispanic ethnicity
• Black or Hispanic people are at higher risk than white people.[6] [25] The mechanism is not known but is thought to be due in part to a higher incidence of diseases such as diabetes and hypertension in these populations. Additionally, in black and Hispanic populations, genetic factors such as apolipoprotein L1 risk variants increase the risk for non-diabetic kidney disease.
family history of CKD

- People with a close family member with the disease are at a higher risk themselves of developing CKD. The mechanism is thought to be due in part to genetic susceptibility to certain disease states, such as diabetes, hypertension, polycystic kidney disease, Alport syndrome, and possibly glomerular syndromes, such as IgA nephropathy and focal segmental glomerulosclerosis.

autoimmune disorders

- Autoimmune disorders such as systemic lupus erythematosus, rheumatoid arthritis, sarcoidosis, and Sjogren syndrome may cause glomerular or tubulo-interstitial CKD.

male sex

- Men are at a higher risk than women. The mechanism of renal injury is not known but is thought to be related to differences in sex hormones that may interact with glomerular and mesangial cells, which have differential attraction of inflammatory mediators and cytokines, resulting in renal injury and scarring.

long-term use of nonsteroidal anti-inflammatory drugs

- Long-term use of anti-inflammatory analgesics for rheumatological disorders and pain control have been associated with the development of CKD. Nonsteroidal anti-inflammatory drugs, and previously phenacetin, have been described as causing analgesic nephropathy.

high uric acid levels

- There is an expected increase in uric acid levels with advancing CKD. Literature also discusses uric acid as a contributory factor to CKD worsening. However, trials of urate-lowering treatment did not result in clinically meaningful benefits to kidney outcomes.

History & examination factors

Key diagnostic factors

fatigue (common)

- Signs and symptoms of CKD are often vague and commonly include fatigue, which may be due to uremia or anemia. Anemia is associated with CKD due to the lack of erythropoietin produced by the kidney, usually once the glomerular filtration rate declines to <50 mL/minute/1.73 m². There can also be other deficiency anemias (e.g., iron) that manifest during assessment of CKD.

edema (common)

- Periorbital and peripheral edema develop as a result of salt and water retention as the glomerular filtration rate declines, and may be exacerbated by hypoalbuminemia.

nausea with/without vomiting (common)

- Thought to be due to an accumulation of toxic waste products in the circulation, such as urea that is not excreted by the kidney. As kidney failure progresses to the more advanced stages of uremia, patients may report vomiting. They may also report a metallic taste in the mouth further worsening the nausea.

pruritus (common)
Chronic kidney disease

Diagnosis

• Thought to be due to an accumulation of toxic waste products in the circulation and under the skin, such as urea that is not excreted by the kidney.[37]

restless legs (common)
• A symptom of uremia.[37] Present in all stages of CKD.[42]

anorexia (common)
• Thought to be due to an accumulation of toxic waste products in the circulation, such as urea that is not excreted by the kidney

infection-related glomerular disease (uncommon)
• Infections such as hepatitis B and C, syphilis, and streptococcal pharyngitis are associated with glomerular disorders.
• A kidney biopsy is essential in these cases to determine the pathologic lesion.

Other diagnostic factors

arthralgia (common)
• If patient has concomitant autoimmune disorder.

enlarged prostate gland (common)
• Prostate exam in men should be performed to exclude obstructive uropathy.

foamy-appearing urine (uncommon)
• Indicative of proteinuria.

cola-colored urine (uncommon)
• Indicative of hematuria.

rashes (uncommon)
• Ecchymosis and purpura are signs of hematologic consequences of CKD.
• Patient may have concomitant autoimmune disorder (e.g., systemic lupus erythematosus and butterfly rash).

dyspnea (uncommon)
• Associated with pulmonary edema due to reduced urine output in worsening disease.

orthopnea (uncommon)
• Associated with pulmonary edema due to reduced urine output in worsening disease.

seizures (uncommon)
• Occurs in advanced-stage disease.[39]
• Thought to be due to an increase in neurotoxins that are not excreted by the kidney.

retinopathy (uncommon)
• Fundoscopy is a key examination in determining presence of diabetic or hypertensive retinopathy, as evidence of microvascular damage, which occurs in uncontrolled diabetes/hypertension. Diabetic and hypertensive patients should be screened for such changes.
## Chronic kidney disease

### Diagnostic tests

#### 1st test to order

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
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<tbody>
<tr>
<td><strong>renal chemistry</strong></td>
<td>elevated serum creatinine; electrolyte abnormalities</td>
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<tr>
<td>• Includes sodium, potassium, chloride, bicarbonate, BUN, creatinine, and glucose.</td>
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<td>• Serum creatinine alone is insufficient to determine CKD, and may be falsely low in conditions of low muscle mass, as in older or malnourished people, or patients with liver failure.</td>
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<tr>
<td>• Normal creatinine in men is 0.8 to 1.4 mg/dL, and in women 0.6 to 1.1 mg/dL. However, there is significant variation due to calibration methods between laboratories.</td>
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<tr>
<td>• Electrolyte abnormalities may indicate an underlying cause of CKD, such as tubular disorders. Adaptations in acid excretion by the kidneys initially prevent a fall in serum bicarbonate concentration, but as GFR declines, metabolic acidosis develops.</td>
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<tr>
<td><strong>estimation of GFR</strong></td>
<td>&lt;60 mL/minute/1.73 m²</td>
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<tr>
<td>• A GFR estimating equation using serum creatinine is recommended for initial assessment.</td>
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<tr>
<td>• Determines more accurately, by mathematical equations such as Cockcroft-Gault, the Modification of Diet in Renal Disease Formula, or the CKD EPI equation, the GFR and the severity and stage of CKD.</td>
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<tr>
<td>• Formulas have not been proven to be reliable estimators in patients with a GFR &gt;59 mL/minute/1.73 m².</td>
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<tr>
<td><strong>serum cystatin C and cystatin C-based estimation of GFR</strong></td>
<td>reduced muscle mass will lead to overestimation; increased muscle mass to underestimation of the GFR</td>
</tr>
<tr>
<td>• Warranted in specific circumstances when GFR estimates based on serum creatinine are thought to be inaccurate, such as in people with extremes of muscle mass (e.g., bodybuilders, people with muscle wasting disorders, older or malnourished people).</td>
<td></td>
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<tr>
<td><strong>urinalysis</strong></td>
<td>hematuria and/or proteinuria</td>
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<tr>
<td>• Screening test to determine for pathologic markers of kidney damage excreted in the urine.</td>
<td></td>
</tr>
<tr>
<td><strong>urinary albumin</strong></td>
<td>moderately increased (AER 30-300 mg/day; ACR 3-30 mg/mmol (30-300 mg/g))</td>
</tr>
<tr>
<td>• Classification of CKD requires quantification of urinary albumin as based on albumin excretion rate (AER) or albumin to creatinine ratio (ACR). Moderately increased albuminuria is a risk factor for the development of progressive CKD and coronary artery disease associated with diabetes and hypertension. Indicated in patients with diabetes and CKD if there was no evidence of proteinuria on urine dipstick.</td>
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<tr>
<td><strong>renal ultrasound</strong></td>
<td>small kidney size; presence of obstruction/ hydronephrosis; kidney stones</td>
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<tr>
<td>• Helps to diagnose CKD if kidney atrophy is present and diagnoses obstruction with hydronephrosis or bladder retention.</td>
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**Other tests to consider**

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
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<tbody>
<tr>
<td><strong>kidney biopsy</strong></td>
<td>variable depending on etiology</td>
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<tr>
<td>• Helps to determine pathologic diagnosis of CKD in glomerular nephrotic and nephritic syndromes, and in people with diabetes with atypical presentations such as rapidly progressive kidney failure. Also essential in determining whether pathologic lesions are due to infection (e.g., hepatitis B and C, syphilis, and streptococcal pharyngitis). Provides insight into treatment options based on severity or chronicity of scarring of glomeruli and interstitium.</td>
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<tr>
<td><strong>plain abdominal radiograph</strong></td>
<td>may reveal calcium-containing kidney stones</td>
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<tr>
<td>• Nonspecific test that may aid in the detection of calcium-containing kidney stones, as medication and urate stones are not apparent on plain radiography.</td>
<td></td>
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<tr>
<td><strong>abdominal CT</strong></td>
<td>may reveal kidney stones, renal masses, or cysts</td>
</tr>
<tr>
<td>• Imaging test that is helpful to determine the presence or absence of kidney stones and confirms obstructive component. It is also helpful to further evaluate cystic lesions or mass lesions in the kidney. Intravenous contrast is used with caution in high-risk patients, such as those with CKD with a reduction in the estimated GFR &lt;60 mL/minute, as it can cause acute kidney injury. Prophylaxis with intravenous normal saline may be indicated or considered in some patients.[46]</td>
<td></td>
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<tr>
<td><strong>abdominal MRI</strong></td>
<td>may reveal mass lesions in the kidney</td>
</tr>
<tr>
<td>• Imaging test that further characterizes mass lesions in the kidney, such as renal cell carcinoma.</td>
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<tr>
<td>• Gadolinium-based MRI examinations have been associated with nephrogenic systemic fibrosis in patients with kidney disease. However, not all gadolinium-containing contrast agents have the same risk of nephrogenic systemic fibrosis, and the benefits of gadolinium-based MRI use may exceed its risk.[47]</td>
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## Differential diagnosis

<table>
<thead>
<tr>
<th>Condition</th>
<th>Differentiating signs / symptoms</th>
<th>Differentiating tests</th>
</tr>
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| Diabetic kidney disease    | • History of poorly controlled diabetes for about 10 years. Often with coexisting diabetic retinopathy and other stigmata of diabetic microvascular disease. | • HbA1c is typically >7%.  
• Diagnostic tests include urinalysis for microalbumin or protein and a serum creatinine for GFR assessment.  
• The quantification of proteinuria is variable over time and will decrease as the GFR declines.  
• Urine microalbumin is helpful to confirm the diagnosis of early diabetic nephropathy prior to the onset of macroalumminuria.  
• Kidney ultrasound will typically show small, atrophic kidneys only in late stages of the disease, once substantial renal injury occurs. |
| Hypertensive nephrosclerosis | • History of poorly controlled hypertension for years. More common in black people than white people. | • Diagnostic tests include urinalysis for microalbumin or protein and a serum creatinine for GFR assessment.  
• The urine sediment is described as bland, without formed elements or hematuria. Quantification of proteinuria is <2 g/24 hours.  
• Kidney ultrasound typically reveals small, atrophic kidneys. |
| Ischemic nephropathy       | • History of long-standing essential hypertension that suddenly is uncontrolled. More common in white people and older people.  
• Often will have a history of atherosclerotic disease such as coronary artery disease or peripheral vascular disease. There is also a history of tobacco abuse and hyperlipidemia. | • The urine sediment is described as bland, without formed elements or hematuria. Quantification of proteinuria is <2 g/24 hours.  
• Kidney ultrasound reveals asymmetric kidney size of ≥2.5 cm with unilateral disease, and duplex scan demonstrates an increase in the resistive index, suggesting obstruction.  
• ACE inhibitor renogram, CT angiogram, magnetic resonance angiogram, or renal arteriogram (test of choice) demonstrates |
<table>
<thead>
<tr>
<th>Condition</th>
<th>Differentiating signs / symptoms</th>
<th>Differentiating tests</th>
</tr>
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</table>
| **Obstructive uropathy** | • More common in men and older people. Often due to prostatic enlargement or cancer.  
• Typical symptoms include urinary frequency, hesitancy, inability to empty the bladder completely, and decrease in urinary stream.  
• Urinary tract infections may develop.  
• Rectal exam may reveal prostatic enlargement or nodules. | • Kidney ultrasound is the diagnostic test of choice to document kidney obstruction. It would show hydrenephrosis, and there may also be post-void residual volume in those cases when there is obstruction to bladder flow. |
| **Nephrotic syndrome**  | • Often associated with a more sudden onset of hypertension, or acceleration of essential hypertension and development of periorbital and peripheral edema. | • Laboratory evidence may reveal hypoalbuminemia, hyperlipidemia and an increase in serum creatinine. Urinalysis has proteinuria as defined at >3.5 g/24 hours.  
• A kidney biopsy is required to determine the pathologic lesion for nephrotic syndrome.  
• Serologic tests for secondary causes of nephrotic syndrome such as antinuclear antibody in systemic lupus erythematosus, HIV in focal segmental glomerulosclerosis, and hepatitis B and C in membranous nephropathy, and serum protein electrophoresis for amyloidosis, are often helpful in confirming the diagnosis of nephrotic syndrome. |
| **Glomerulonephritis**  | • Often associated with a sudden onset of hypertension or acceleration of essential hypertension.  
• Patients with autoimmune disorders may have a skin rash or arthritis; postinfectious glomerulonephritis has a recent history of a pharyngeal or cutaneous infection; bloody diarrhea is | • Laboratory evidence reveals an increased serum creatinine, and urinalysis is significant for hematuria and proteinuria.  
• Urine sediment is evaluated for the presence of dysmorphic red blood cells (RBC) and RBC casts, which are diagnostic of glomerulonephritis. |
**Diagnosis**

**Diagnostic criteria**

**Diagnostic classification[1]**

CKD is divided into 6 distinct categories based on glomerular filtration rate (GFR). The GFR category (G1-G5) has the same GFR thresholds as the CKD stages 1 to 5 recommended previously, as follows:[1]

- G1: GFR >90 mL/minute/1.73 m², and evidence of kidney damage based on pathologic diagnosis, abnormalities of radiographic imaging, or laboratory findings such as hematuria and/or proteinuria
- G2 GFR 60 to 89: mL/minute/1.73 m²
- G3a GFR 45 to 59: mL/minute/1.73 m²
- G3b GFR 30 to 44: mL/minute/1.73 m²
- G4 GFR 15 to 29: mL/minute/1.73 m²
- G5 GFR <15: mL/minute/1.73 m².

The albumin category is also documented based on albumin excretion rate (AER) or albumin to creatinine ratio (ACR):

- A1 AER <30 mg albumin/24 hours or ACR <30 mg/g: normal to mildly increased
- A2 AER 30 to 300 mg albumin/24 hours or ACR of 30 to 300 mg/g: moderately increased
- A3 AER >300 mg albumin/24 hours or ACR >300 mg/g: severely increased.
Chronic kidney disease

Step-by-step treatment approach

For updates on diagnosis and management of coexisting conditions during the pandemic, see our topic "Management of coexisting conditions in the context of COVID-19".

All etiologies of CKD are progressive. The main goal of treatment is to slow the progressive loss of kidney function and prevent the need for renal replacement therapy or kidney transplantation. The most important factor in treatment is to identify patients early in the course of their disease and classify the stage of CKD (GFR category G1-G5) so that risk factor modification can ensue and identification of comorbidities such as anemia and secondary hyperparathyroidism may be treated.

CKD is divided into 6 distinct categories based on glomerular filtration rate (GFR). The GFR category (G1-G5) has the same GFR thresholds as the CKD stages 1 to 5 recommended previously:[1]

- G1: GFR >90 mL/minute/1.73 m², and evidence of kidney damage based on pathologic diagnosis, abnormalities of radiographic imaging, or laboratory findings such as hematuria and/or proteinuria
- G2: GFR of 60 to 89 mL/minute/1.73 m²
- G3a: GFR of 45 to 59 mL/minute/1.73 m²
- G3b: GFR of 30 to 44 mL/minute/1.73 m²
- G4: GFR of 15 to 29 mL/minute/1.73 m²
- G5: GFR <15 mL/minute/1.73 m².

GFR category G1 to G4 first-line therapy

The major cause of death for patients with CKD is cardiovascular disease. Therefore, treatment of cardiovascular risk factors, such as optimizing glycemic control, optimizing blood pressure (BP) with an ACE inhibitor or an angiotensin-II receptor antagonist, introducing lipid-lowering agents (e.g., statins, ezetimibe), and reducing proteinuria is recommended.[50] [51] [52]

Diabetes

- Glycemic goals should be individualized. For many patients, the goal of HbA1c <7% is appropriate. However, HbA1c 7.0% to 7.9% may be more appropriate in some patients, such as those with advanced age, limited life expectancy, known cardiovascular disease, high risk of severe hypoglycemia, or difficulty achieving lower HbA1c goals despite the use of multiple antihyperglycemic medications and insulin.[53] In patients with diabetes and CKD, there is a risk for hypoglycemia because of impaired kidney clearance of medications, such as insulin (two-thirds of insulin is degraded by the kidney) or sulfonylureas, and because of impaired kidney gluconeogenesis.
- Patients with type 1 diabetes require treatment with insulin, regardless of whether they are on dialysis or not.
- In patients with type 2 diabetes, some specific antihyperglycemic medications significantly reduce all-cause or cardiovascular mortality, or major cardiovascular events or renal complications in some patient subgroups, and may be considered independently of HbA1c targets.[54] [55] [56] Among the antihyperglycemic medications that reduce cardiovascular mortality in some patient subgroups are metformin (if estimated glomerular filtration rate [eGFR] is >30 mL/min/1.73 m²), sodium-glucose co-transporter 2 (SGLT2) inhibitors (empagliflozin, canagliflozin), and glucagon-like peptide-1 (GLP-1) agonists (liraglutide).[57] [58] [55] [59]
Chronic kidney disease

Treatment

- There is evidence that the use of SGLT2 inhibitors prevents major kidney outcomes (e.g., dialysis, transplantation, or death due to kidney disease) in people with type 2 diabetes.[60] SGLT2 inhibitors, in addition to reducing hyperglycemia, have renal benefits through independent effects on renal tubular glucose reabsorption, weight, BP, intraglomerular pressure, albuminuria, and slowed GFR loss.[61] [62] The use of SGLT2 inhibitors is not generally recommended in patients with an eGFR of <45 mL/min/1.73 m² (<60 mL/min/1.73 m² for ertugliflozin); however, the CREDENCE trial included patients with an eGFR 30 to 90 mL/min/1.73 m² and demonstrated a decreased risk of kidney failure and cardiovascular events.[63] Use of SGLT2 inhibitors is contraindicated in patients with an eGFR of <30 mL/min/1.73 m², including patients with end-stage renal disease (ESRD) who are on dialysis. As a class of drugs, GLP-1 agonists have beneficial effects on cardiovascular, mortality, and kidney outcomes in patients with type 2 diabetes.[64]

- Experience with GLP-1 agonists in patients with renal dysfunction is limited; therefore, these agents should be used with caution.[65] Liraglutide, albiglutide, dulaglutide, and semaglutide are not renally excreted and are the preferred agents in this class.

- Studies report that dipeptidyl peptidase-4 (DPP-4) inhibitors are renoprotective, but did not have a cardiovascular benefit.[66] [67] Some DPP-4 inhibitors require dose adjustment in renal impairment.

Hypertension

- Hypertension is one of the greatest risk factors for the progression of CKD, regardless of etiology. Most patients with CKD will require at least two or three different types of antihypertensive agent to achieve the optimal BP control.

- There is ongoing debate on optimal BP target for patients with CKD. The 2014 Joint National Committee 8 redefined the target BP goal for patients with CKD as <140/90 mmHg.[68] However, the 2017 American College of Cardiology/American Heart Association guideline recommends adults with hypertension and CKD should be treated to a BP goal of less than 130/80 mmHg.[69] There may be benefit in strict BP control to reduce the relative risk of death, and delay the onset of ESRD in some subgroups of patients with CKD (age ≥40 years, body mass index ≥30 kg/m²).[70] [71] The Kidney Disease: Improving Global Outcomes (KDIGO) guidelines recommend a BP goal of ≤130/80 mmHg if urinary albumin excretion is ≥30 mg/24 hours in patients with and without diabetes.[72]

- A combination of antihypertensive agents should be used to meet the target BP goal (except that ACE inhibitors and angiotensin-II receptor antagonists should not be combined within the same regimen).

- ACE inhibitors and angiotensin-II receptor antagonists have been shown in numerous clinical trials to slow the progression of CKD and delay the need for renal replacement therapy in both diabetic and nondiabetic CKD.[73] [74] [75] In a meta-analysis of patients with CKD, blockade of the renin angiotensin system with either ACE inhibitors or angiotensin-II receptor antagonists was associated with a reduction in the risk of myocardial infarction, congestive heart failure, and total cardiovascular outcomes when compared with treatment with either placebo or controlled arms with other antihypertensive agents.[76] This emphasizes the importance of these agents as the first-line therapy in the treatment of CKD.

- Although previously thought that a complete blockade of the renin angiotensin system with combination therapy of ACE inhibitors and angiotensin-II receptor antagonists or direct renin inhibitors would delay progression in CKD, clinical trial results have failed to confirm any such benefit. In the ONTARGET trial, individuals were assigned to telmisartan, ramipril, or combination therapy, evaluating the effectiveness of dual therapy on cardiac and renal outcomes.[77] The
study concluded that there was no difference in deaths from cardiovascular causes, in myocardial infarctions, cerebrovascular accidents, or hospitalizations for congestive heart failure, in the treatment groups. Also, the rates of renal outcomes defined as the first time for dialysis, death, or doubling of the serum creatinine were greater in the combination arm as compared with the single-based therapy arms. Thus, there is currently no clinical evidence that supports the use of this combination in the CKD population, and such therapy should not be recommended due to the increased risk of hyperkalemia and acute kidney injury. Although not recommended for CKD, combination therapy with ACE inhibitors and angiotensin-II receptor antagonists is sometimes used in patients with nephrotic syndromes and glomerulonephritis to reduce proteinuria.

- Other classes of antihypertensive agents (e.g., thiazide or thiazide-like diuretics, beta-blockers, etc.) can be combined with ACE inhibitors or angiotensin-II receptor antagonists if target BP is not achieved with these first-line agents.

- Aliskiren was previously recommended for use in combination with ACE inhibitors or angiotensin-II receptor antagonists; however, in December 2011, the manufacturer recommended that physicians should no longer prescribe aliskiren-containing products with these two classes of drugs based on the results, and subsequent early termination, of the ALTITUDE trial.[78] The trial assessed the effects of aliskiren in combination with ACE inhibitors or angiotensin-II receptor antagonists in people with type 2 diabetes at high risk for cardiovascular and renal events, and found an increased risk for non-fatal stroke, renal complications, hyperkalemia, and hypotension in patients taking the drug for 18-24 months. The Food and Drug Administration (FDA) now recommends that the combination of aliskiren with ACE inhibitors or angiotensin-II receptor antagonists is contraindicated in patients with diabetes because of the risk of renal impairment, hypotension, and hyperkalemia. The FDA also recommends that this combination of drugs be avoided in patients with moderate to severe renal impairment (i.e., GFR <60 mL/minute/1.73 m²).

Dyslipidemia

- Dyslipidemia is common in patients with CKD. Although specific treatment targets for cholesterol and low-density lipoprotein have been recommended for CKD patients, this "treat to target" approach has not been well established in clinical trials.

- As such, the KDIGO guidelines recommend that CKD patients not on dialysis should start treatment with a statin without the need for routine follow-up to check lipid values, or to change treatment regimen based on set targets (i.e., a "treat and forget" approach).[50] For patients ages ≥50 years with CKD GFR category G3 or G4, ezetimibe can be combined with the statin simvastatin.[51]

- Statin therapy has been shown to have cardioprotective effects in patients with CKD.[79] [80] [81] [82] In those individuals not on dialysis therapy, the use of statins in a large meta-analysis resulted in the reduction of all-cause mortality by 21% (relative risk [RR] 0.79, 95% CI 0.69 to 0.91) and cardiovascular mortality by 23% (RR 0.77, 95% CI 0.69 to 0.87).[83] It was noted that there was no difference in adverse effects for statin users as compared with those in the placebo arms. Despite previous evidence that statins may be renoprotective via anti-inflammatory effects in the kidney, the use of statins in these trials did reduce proteinuria but overall did not improve kidney function.

- Unfortunately, the beneficial effect of statin use in CKD has not been shown in the dialysis population. In both single investigations and a recent meta-analysis, statin use in patients undergoing dialysis did not improve all-cause mortality or cardiovascular-related deaths.[84]
GFR category G1 to G4 intolerant to first-line therapy

If a patient is unable to tolerate either an ACE inhibitor or an angiotensin-II receptor antagonist due to adverse effects, then an alternative is warranted. Nondihydropyridine calcium-channel blockers have been demonstrated to have more proteinuric-lowering effects than other antihypertensive agents. Clinical trials in both diabetic and nondiabetic CKD have demonstrated greater protein-lowering effects than other classes of antihypertensive agents.[85]

GFR category G2

The directed therapy is to continue to modify cardiovascular risk factors, but also estimate the rate of loss of kidney function to determine the eventual need for renal replacement therapy (i.e., dialysis, transplant).

GFR category G3a/G3b

Education can play a significant role in delaying progression of CKD, as well as helping the patient understand his/her options if CKD progresses.[86] [87] [88] Most CKD-related complications occur during this stage of transition (GFR category G3a/G3b). Identification of comorbidities such as anemia and secondary hyperparathyroidism is recommended, and treatment commenced if required.

Treatment of anemia with the use of erythropoietin-stimulating agents is recommended for patients with CKD after other causes of anemia such as iron, vitamin B12, folate, or blood loss have been excluded. Patients with CKD frequently have iron deficiency, and iron replacement should be considered as a goal of treatment.

Erythropoietin stimulating therapy may be initiated if the hemoglobin (Hb) falls to <10 g/dL and the patient has signs and symptoms of anemia. The target Hb for patients with CKD on erythropoietin therapy has changed in the last several years but clinical expert opinion suggests that a target of 10-11 g/dL is appropriate, as normalization of Hb has resulted in increased risk for death and cardiovascular disease in this population.[89] [90] In the TREAT study of patients with diabetes with CKD and anemia, treatment with the erythropoietin-stimulating agent darbepoetin failed to show a beneficial effect of active treatment on cardiovascular events, death, or ESRD as compared with those receiving placebo (individuals would receive a rescue dose of medication if the hemoglobin fell below 9 g/dL).[91] Interestingly, as in other studies of anemia treatment in CKD, the TREAT investigators demonstrated that individuals in the active treatment arm had an increased risk of stroke (RR 1.92, 95% CI 1.38 to 2.68).[92] In their opinion, the risks of treatment may outweigh the benefits, and discussion between the patient and physician should ensue prior to treatment initiation.[91] [93] [94] [95] All patients should have an evaluation of iron stores if erythropoietin therapy is planned. The goal ferritin for those not on hemodialysis is >100 nanograms/mL, while for those on hemodialysis is <200 nanograms/mL. All patients should have a transferrin saturation >20%. Iron replacement can be given orally or parenterally.[96]

For secondary hyperparathyroidism, calcium, phosphorus, and intact parathyroid hormone (PTH) levels should be measured every 6 to 12 months. The calcium and phosphorus levels should be maintained in the normal range with dietary restriction and/or phosphate-binding medications. The optimal PTH level is currently not known. It is recommended to exclude concomitant 25-OH vitamin D deficiency and prescribe 25, dihydroxyvitamin D if <30 nanograms/dL. For those with GFR category G3 to G5 CKD not on dialysis, it is not routinely recommended to use active vitamin D analogs due to the risk of hypercalcemia and lack of improvement in clinically relevant outcomes.[97] Use of active vitamin D analog therapy in patients with CKD not requiring dialysis is indicated if hyperparathyroidism is progressive or severe.[97] [98] There is
emerging evidence that the use of non-calcium-based phosphate binders has a survival advantage over calcium-based phosphate binders in patients with CKD.[97] [99] [Evidence B]

**GFR category G4**

Patients need to be educated about renal replacement therapy such as hemodialysis, peritoneal dialysis, and kidney transplantation.[87] [100] Patients should be referred to surgery for dialysis access and/or evaluated for kidney transplantation, based on patient preference for renal replacement modality at this stage. All patients should undergo CKD education for modality choice.[87] Patient preference, family support, underlying comorbid conditions, and proximity to a dialysis facility should be addressed when choosing a modality or consideration for palliative care.[101] All patients who are proceeding with hemodialysis should be educated on vein preservation with limiting venipuncture and intravenous access to the access arm.[102] Kidney transplantation is indicated once the eGFR is <20 mL/minute and the patient has been evaluated and undergone the required testing process by a transplant team.

Treatment of anemia and secondary hyperparathyroidism should be continued. It is recommended to check serum calcium and phosphate every 3 to 6 months, and intact PTH every 6 to 12 months.[97] [Evidence C] Additionally, for those patients who develop metabolic acidosis, supplementation with oral sodium bicarbonate to a target serum bicarbonate level of >20 mEq/L has been shown to slow progression of CKD and improve nutritional parameters. Oral sodium bicarbonate is well tolerated in this group.[103]

**GFR category G5 and uremia**

Renal replacement therapy may be initiated once patients have G5 disease and/or signs of uremia such as weight loss, lack of appetite, nausea, vomiting, acidosis, hyperkalemia, or fluid overload.[1] Those with G5 CKD on dialysis, calcium, phosphorus, and intact PTH should be managed with phosphate binding agents, calcimimetics, active vitamin D analogs, or a combination of these therapies, based on serial laboratory assessments of calcium and phosphate every 1 to 3 months, and PTH every 3 to 6 months.[97] [Evidence C] Calcimimetics (e.g., cinacalcet, etelcalcetide) negatively feedback on the parathyroid glands and do not have the consequences of calcium augmentation.[104] Cinacalcet lowers PTH levels in patients with CKD and secondary hyperparathyroidism both prior to and after the initiation of dialysis, but it is associated with hypocalcemia, and long-term benefits are not known.[105] [106]

There is no other medical therapy to keep patients alive once they have reached the need for dialysis, other than kidney transplantation. Of note, patients aged over 80 years and those with significant comorbidities, such as advanced congestive heart failure, may do poorly with dialysis and frequently are not considered transplant candidates. For these patients, and for all patients approaching ESRD for that matter, the treating nephrologist should have a discussion with the patient regarding end of life care and palliative care as an additional option.[107]

For those who are considered transplant candidates, transplant confers a significant survival advantage over maintenance dialysis therapy, predominantly due to a decrease in the risk of cardiovascular death. All patients who are on dialysis therapy are potentially eligible for kidney transplantation. A transplant center including a nephrologist and transplant surgeon will determine the final eligibility and status of the patient for kidney transplantation, after a complete medical history and evaluation.[108] [109]

**Other measures**

Although data are more limited in the CKD population than in the general population, tobacco cessation and weight loss are recommended. Severe protein restriction should not be recommended until late GFR
Chronic kidney disease

Treatment

category G4 or G5 disease as a management strategy to control uremia in order to delay the initiation of dialysis.[110] Severe protein restriction may result in malnourishment and poorer outcomes.[111] Aspirin use has also been beneficial for cardioprotection in those with CKD, although there is a higher risk for minor bleeding than in the general population.

Treatment details overview

Please note that formulations/routes and doses may differ between drug names and brands, drug formularies, or locations. Treatment recommendations are specific to patient groups: see disclaimer
<table>
<thead>
<tr>
<th>Acute</th>
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<tbody>
<tr>
<td><strong>GFR category G1 to G2 without uremia</strong></td>
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<tr>
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Treatment options

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Acute

GFR category G1 to G2 without uremia

1st ACE inhibitor or angiotensin-II receptor antagonist

Primary options

» lisinopril: 2.5 to 5 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment

OR

» ramipril: 1.25 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment

OR

» enalapril: 2.5 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment

OR

» perindopril erbumine: 2 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment

OR

» trandolapril: 0.5 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment

OR

» captopril: 12.5 to 25 mg orally two to three times daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment

OR

» losartan: 50 mg orally once daily initially, adjust dose gradually according to response, maximum 100 mg/day

OR
Chronic kidney disease

Treatment

Acute

» irbesartan: 75 mg orally once daily initially, adjust dose gradually according to response, maximum 300 mg/day

OR

» telmisartan: 20 mg orally once daily initially, adjust dose gradually according to response, maximum 80 mg/day

OR

» eprosartan: 300 mg orally once daily initially, adjust dose gradually according to response, maximum 600 mg/day

» The 2014 Joint National Committee 8 redefined the target blood pressure (BP) goal for patients with CKD as <140/90 mmHg, given the evidence from clinical trials that this is associated with the lowest risk of cardiovascular outcomes and mortality.[68] However, the 2017 American College of Cardiology/American Heart Association guideline recommends adults with hypertension and CKD should be treated to a BP goal of less than 130/80 mmHg.[69] The Kidney Disease: Improving Global Outcomes guidelines recommend a BP goal of ≤130/80 mmHg if urinary albumin excretion is ≥30 mg/24 hours in patients with and without diabetes.[72]

» Clinical trials in both diabetic and nondiabetic kidney disease have demonstrated that ACE inhibitors or angiotensin-II receptor antagonists are first-line agents for controlling BP and reducing proteinuria in this population.

» Evidence for the use of ACE inhibitors and angiotensin-II receptor antagonists in combination for CKD is controversial. Although current clinical evidence does not support the routine use of ACE inhibitors and angiotensin-II receptor antagonists in combination for the treatment of CKD, it is sometimes given to patients with nephrotic syndromes and glomerulonephritis to reduce proteinuria.[77]

» Both classes of drug may be associated with hyperkalemia and acute kidney injury, more commonly in older people, those with an estimated glomerular filtration rate (eGFR) <30 mL/minute/1.73 m², and with use of longer-acting agents. These complications are usually reversible with medication discontinuation and appropriate treatment.
Acute

Doses should be low initially and adjusted gradually according to clinical response.

plus statin

Treatment recommended for ALL patients in selected patient group

Primary options

» simvastatin: 20-40 mg orally once daily

OR

» pravastatin: 40 mg orally once daily

OR

» rosvuastatin: 5-10 mg orally once daily

OR

» atorvastatin: 10-20 mg orally once daily

Statin therapy has been shown to have cardioprotective effects in patients with CKD.[79] [80] [81] [82] In those individuals not on dialysis therapy, the use of statins in a large meta-analysis resulted in the reduction of all-cause mortality by 21% (relative risk [RR] 0.79, 95% CI 0.69 to 0.91) and cardiovascular mortality by 23% (RR 0.77, 95% CI 0.69 to 0.87).[83]

Total cholesterol and low-density lipoprotein treatment targets for patients with CKD have not been well established in clinical trials. As such, the Kidney Disease: Improving Global Outcomes guidelines recommend that CKD patients ≥50 years or those with a high risk of cardiovascular mortality, not on dialysis should be treated with a statin without the need for routine follow-up to check lipid values, or to change medication dose regimens based on set targets (i.e., a "treat and forget" approach).[50]

Statin therapy has been associated with liver dysfunction and myopathy and should be monitored in patients with CKD.

adjunct additional antihypertensive therapy

Treatment recommended for SOME patients in selected patient group

Primary options

» chlorthalidone: 12.5 to 25 mg orally once daily initially, adjust dose gradually according to response, maximum 50 mg/day
Chronic kidney disease

Treatment

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<td>» hydrochlorothiazide: 12.5 mg orally once daily initially, adjust dose gradually according to response, maximum 50 mg/day</td>
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<td>» atenolol: 25 mg orally once daily initially, adjust dose gradually according to response, maximum 25-50 mg/day</td>
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<td>» metoprolol succinate: 25 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 100 mg/day</td>
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<tr>
<td>» nifedipine: 30-60 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 90 mg/day (120 mg/day for some brands)</td>
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<tr>
<td>» amlodipine: 5 mg orally once daily initially, adjust dose gradually according to response, maximum 10 mg/day</td>
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<td>» felodipine: 2.5 mg orally once daily initially, adjust dose gradually according to response, maximum 20 mg/day</td>
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<tr>
<td>» spironolactone: 12.5 mg orally once daily initially, adjust dose gradually according to response, maximum 200 mg/day given in 2-4 divided doses</td>
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Secondary options

» hydralazine: 10 mg orally three to four times daily initially, adjust dose gradually according to response, maximum 300 mg/day

OR
Acute

- **minoxidil**: 5 mg orally once daily initially, adjust dose gradually according to response, maximum 40 mg/day
  
  OR
  
  - **clonidine**: 0.1 mg orally (immediate-release) twice daily initially, adjust dose gradually according to response, maximum 0.6 mg/day

**adjunct glycemic control**

Treatment recommended for SOME patients in selected patient group

- In patients with diabetes, glycemic goals should be individualized. For many patients, the goal of HbA1c <7% is appropriate. However, HbA1c 7.0% to 7.9% may be more appropriate in some patients, such as those with advanced age, limited life expectancy, known cardiovascular disease, high risk of severe hypoglycemia, or difficulty achieving lower HbA1c goals despite the use of multiple antihyperglycemic medications and insulin.[53]

In patients with diabetes and CKD, there is a risk for hypoglycemia because of impaired kidney clearance of medications, such as insulin (two-thirds of insulin is degraded by the kidney) or sulfonlureas, and because of impaired kidney gluconeogenesis.

- Patients with type 1 diabetes require treatment with insulin, regardless of whether they are on dialysis or not.

- Some specific antihyperglycemic medications used by patients with type 2 diabetes significantly reduce all-cause or cardiovascular mortality, or major cardiovascular events or renal complications in some patient subgroups, and may be considered independently of HbA1c targets.[54] [55] [56] Among the antihyperglycemic medications that reduce cardiovascular mortality in some patient subgroups are metformin, sodium-glucose co-transporter 2 (SGLT2) inhibitors (empagliflozin, canagliflozin), and glucagon-like peptide-1 (GLP-1) agonists (liraglutide).[57] [58] [55] [59]
There is evidence that the use of SGLT2 inhibitors prevents major kidney outcomes (e.g., dialysis, transplantation, or death due to kidney disease) in people with type 2 diabetes.[60] SGLT2 inhibitors, in addition to reducing hyperglycemia, have renal benefits through independent effects on renal tubular glucose reabsorption, weight, BP, intraglomerular pressure, albuminuria, and slowed GFR loss.[61] The use of SGLT2 inhibitors is not generally recommended in patients with an eGFR of <45 mL/min/1.73 m² (<60 mL/min/1.73 m² for ertugliflozin); however, the CREDENCE trial included patients with an eGFR 30 to 90 mL/min/1.73 m² and demonstrated a decreased risk of kidney failure and cardiovascular events.[63] Use of SGLT2 inhibitors is contraindicated in patients with an eGFR of <30 mL/min/1.73 m², including patients with end-stage renal disease who are on dialysis.

As a class of drugs, GLP-1 agonists have beneficial effects on cardiovascular, mortality, and kidney outcomes in patients with type 2 diabetes.[64] Experience with GLP-1 agonists in patients with renal dysfunction is limited; therefore, these agents should be used with caution.[65] Liraglutide, albiglutide, dulaglutide, and semaglutide are not renally excreted and are the preferred agents in this class.

Studies report that dipeptidyl peptidase-4 (DPP-4) inhibitors are renoprotective, but did not have a cardiovascular benefit.[66] Some DPP-4 inhibitors require dose adjustment in renal impairment.

2nd nondihydropyridine calcium-channel blocker

**Primary options**

- **diltiazem**: 120 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 360 mg/day

OR

- **verapamil**: 120 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 360 mg/day

ACE inhibitors and angiotensin-II receptor antagonists are the superior treatment for patients with CKD.
Chronic kidney disease

Treatment

**Acute**

» If these medications need to be discontinued due to adverse effects such as cough, angioedema, hemodynamic decline in renal function, and/or hyperkalemia, then nondihydropyridine calcium-channel blockers have been demonstrated to have more proteinuric-lowering effects than other antihypertensive agents.[112]

**plus statin**

Treatment recommended for ALL patients in selected patient group

**Primary options**

» **simvastatin**: 20-40 mg orally once daily

OR

» **pravastatin**: 40 mg orally once daily

OR

» **rosuvastatin**: 5-10 mg orally once daily

OR

» **atorvastatin**: 10-20 mg orally once daily

» Statin therapy has been shown to have cardioprotective effects in patients with CKD.[79] [80] [81] [82] In those individuals not on dialysis therapy, the use of statins in a large meta-analysis resulted in the reduction of all-cause mortality by 21% (relative risk [RR] 0.79, 95% CI 0.69 to 0.91) and cardiovascular mortality by 23% (RR 0.77, 95% CI 0.69 to 0.87).[83]

» Total cholesterol and low-density lipoprotein treatment targets for patients with CKD have not been well established in clinical trials. As such, the Kidney Disease: Improving Global Outcomes guidelines recommend that CKD patients not on dialysis should be treated with a statin without the need for routine follow-up to check lipid values, or to change medication dose regimens based on set targets (i.e., a "treat and forget" approach).[50]

» Statin therapy has been associated with liver dysfunction and myopathy and should be monitored in patients with CKD.

**adjunct additional antihypertensive therapy**

Treatment recommended for SOME patients in selected patient group
### Acute

<table>
<thead>
<tr>
<th>Primary options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>chlorthalidone</strong>: 12.5 to 25 mg orally once daily initially, adjust dose gradually according to response, maximum 50 mg/day</td>
</tr>
<tr>
<td>OR</td>
</tr>
<tr>
<td><strong>hydrochlorothiazide</strong>: 12.5 mg orally once daily initially, adjust dose gradually according to response, maximum 50 mg/day</td>
</tr>
<tr>
<td>OR</td>
</tr>
<tr>
<td><strong>atenolol</strong>: 25 mg orally once daily initially, adjust dose gradually according to response, maximum 25-50 mg/day</td>
</tr>
<tr>
<td>OR</td>
</tr>
<tr>
<td><strong>metoprolol succinate</strong>: 25 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 100 mg/day</td>
</tr>
<tr>
<td>OR</td>
</tr>
<tr>
<td><strong>nifedipine</strong>: 30-60 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 90 mg/day (120 mg/day for some brands)</td>
</tr>
<tr>
<td>OR</td>
</tr>
<tr>
<td><strong>amlodipine</strong>: 5 mg orally once daily initially, adjust dose gradually according to response, maximum 10 mg/day</td>
</tr>
<tr>
<td>OR</td>
</tr>
<tr>
<td><strong>felodipine</strong>: 2.5 mg orally once daily initially, adjust dose gradually according to response, maximum 20 mg/day</td>
</tr>
<tr>
<td>OR</td>
</tr>
<tr>
<td><strong>spironolactone</strong>: 12.5 mg orally once daily initially, adjust dose gradually according to response, maximum 200 mg/day given in 2-4 divided doses</td>
</tr>
<tr>
<td>OR</td>
</tr>
</tbody>
</table>
**Acute**

- **alkiren**: 150 mg orally once daily initially, adjust dose gradually according to response, maximum 300 mg/day

**Secondary options**

- **hydralazine**: 10 mg orally three to four times daily initially, adjust dose gradually according to response, maximum 300 mg/day

**OR**

- **minoxidil**: 5 mg orally once daily initially, adjust dose gradually according to response, maximum 40 mg/day

**OR**

- **clonidine**: 0.1 mg orally (immediate-release) twice daily initially, adjust dose gradually according to response, maximum 0.6 mg/day

**Other classes of antihypertensive agents** (e.g., thiazide or thiazide-like diuretics, beta-blockers, etc.) should be added when the target blood pressure is not achieved with the use of a nondihydropyridine calcium-channel blocker.

**adjunct glycemic control**

Treatment recommended for SOME patients in selected patient group

- In patients with diabetes, glycemic goals should be individualized. For many patients, the goal of HbA1c <7% is appropriate. However, HbA1c 7.0% to 7.9% may be more appropriate in some patients, such as those with advanced age, limited life expectancy, known cardiovascular disease, high risk of severe hypoglycemia, or difficulty achieving lower HbA1c goals despite the use of multiple antihyperglycemic medications and insulin.[53]

- In patients with diabetes and CKD, there is a risk for hypoglycemia because of impaired kidney clearance of medications, such as insulin (two-thirds of insulin is degraded by the kidney) or sulfonylureas, and because of impaired kidney gluconeogenesis.

- Patients with type 1 diabetes require treatment with insulin, regardless of whether they are on dialysis or not.

- Some specific antihyperglycemic medications used by patients significantly reduce all-cause or cardiovascular mortality, or major cardiovascular events or renal complications in some patient
subgroups, and some may be considered independently of HbA1c targets.[54] [55] [56] Among the antihyperglycemic medications that reduce cardiovascular mortality in some patient subgroups are metformin, sodium-glucose co-transporter 2 (SGLT2) inhibitors (empagliflozin, canagliflozin), and glucagon-like peptide-1 (GLP-1) agonists (liraglutide).[57] [58] [55] [59]

» There is evidence that the use of SGLT2 inhibitors prevents major kidney outcomes (e.g., dialysis, transplantation, or death due to kidney disease) in people with type 2 diabetes.[60] SGLT2 inhibitors, in addition to reducing hyperglycemia, have renal benefits through independent effects on renal tubular glucose reabsorption, weight, blood pressure, intraglomerular pressure, albuminuria, and slowed GFR loss.[61] [62] The use of SGLT2 inhibitors is not generally recommended in patients with an eGFR of <45 mL/min/1.73 m² (<60 mL/min/1.73 m² for ertugliflozin); however, the CREDENCE trial included patients with an eGFR 30 to 90 mL/min/1.73 m² and demonstrated a decreased risk of kidney failure and cardiovascular events.[63] Use of SGLT2 inhibitors is contraindicated in patients with an eGFR of <30 mL/min/1.73 m², including patients with end-stage renal disease who are on dialysis.

» As a class of drugs, GLP-1 agonists have beneficial effects on cardiovascular, mortality, and kidney outcomes in patients with type 2 diabetes.[64] Experience with GLP-1 agonists in patients with renal dysfunction is limited; therefore, these agents should be used with caution.[65] Liraglutide, albiglutide, dulaglutide, and semaglutide are not renally excreted and are the preferred agents in this class.

» Studies report that dipeptidyl peptidase-4 (DPP-4) inhibitors are renoprotective, but did not have a cardiovascular benefit.[66] [67] Some DPP-4 inhibitors require dose adjustment in renal impairment.

<table>
<thead>
<tr>
<th>GFR category G3 to G4 without uremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st ACE inhibitor or angiotensin-II receptor antagonist</td>
</tr>
<tr>
<td><strong>Primary options</strong></td>
</tr>
<tr>
<td>» <strong>lisinopril</strong>: 2.5 to 5 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment</td>
</tr>
</tbody>
</table>
### Acute

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OR</strong></td>
<td></td>
</tr>
<tr>
<td><strong>»</strong> ramipril</td>
<td>1.25 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment</td>
</tr>
<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td><strong>»</strong> enalapril</td>
<td>2.5 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment</td>
</tr>
<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td><strong>»</strong> perindopril erbumine</td>
<td>2 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment</td>
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<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td><strong>»</strong> trandolapril</td>
<td>0.5 mg orally once daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment</td>
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<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td><strong>»</strong> captopril</td>
<td>12.5 to 25 mg orally two to three times daily initially, adjust dose gradually according to response, maximum dose depends on level of impairment</td>
</tr>
<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td><strong>»</strong> losartan</td>
<td>50 mg orally once daily initially, adjust dose gradually according to response, maximum 100 mg/day</td>
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<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td><strong>»</strong> irbesartan</td>
<td>75 mg orally once daily initially, adjust dose gradually according to response, maximum 300 mg/day</td>
</tr>
<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td><strong>»</strong> telmisartan</td>
<td>20 mg orally once daily initially, adjust dose gradually according to response, maximum 80 mg/day</td>
</tr>
</tbody>
</table>
Chronic kidney disease

**Treatment**

**Acute**

- **eprosartan**: 300 mg orally once daily initially, adjust dose gradually according to response, maximum 600 mg/day

- The Joint National Committee 8 redefined the target blood pressure (BP) goal for patients with CKD as <140/90 mmHg, given the evidence from clinical trials that this is associated with the lowest risk of cardiovascular outcomes and mortality.[68] However, the 2017 American College of Cardiology/American Heart Association guideline recommends adults with hypertension and CKD should be treated to a BP goal of less than 130/80 mmHg.[69] The Kidney Disease: Improving Global Outcomes guidelines recommend a BP goal of ≤130/80 mmHg if urinary albumin excretion is ≥30 mg/24 hours in patients with and without diabetes.[72]

- Clinical trials in both diabetic and nondiabetic kidney disease have demonstrated that ACE inhibitors or angiotensin-II receptor antagonists are first-line agents for controlling BP and reducing proteinuria in this population.

- Evidence for the use of ACE inhibitors and angiotensin-II receptor antagonists in combination for CKD is controversial. Although current clinical evidence does not support the routine use of ACE inhibitors and angiotensin-II receptor antagonists in combination for the treatment of CKD, it is sometimes given to patients with nephrotic syndromes and glomerulonephritis to reduce proteinuria.[77]

- Both classes of drug may be associated with hyperkalemia and acute renal failure, more commonly in older people, those with an estimated GFR <30 mL/minute/1.73 m², and with use of longer-acting agents. These complications are usually reversible with medication discontinuation and appropriate treatment.

**plus statin ± ezetimibe**

Treatment recommended for ALL patients in selected patient group

**Primary options**

- **simvastatin**: 20-40 mg orally once daily

OR

- **pravastatin**: 40 mg orally once daily
### Acute

| OR
| rosvastatin: 5-10 mg orally once daily
| OR
| atorvastatin: 10-20 mg orally once daily
| OR
| ezetimibe/simvastatin: 10 mg (ezetimibe)/20 mg (simvastatin) orally once daily

- Statin therapy has been shown to have cardioprotective effects in patients with CKD.[79][80][81][82] In those individuals not on dialysis therapy, the use of statins in a large meta-analysis resulted in the reduction of all-cause mortality by 21% (relative risk [RR] 0.79, 95% CI 0.69 to 0.91) and cardiovascular mortality by 23% (RR 0.77, 95% CI 0.69 to 0.87).[83]

- Total cholesterol and low-density lipoprotein treatment targets for patients with CKD have not been well established in clinical trials. As such, the Kidney Disease: Improving Global Outcomes guidelines recommend that GFR category G3 or G4 CKD patients not on dialysis should be treated with a statin without the need for routine follow-up to check lipid values, or to change medication dose regimens based on set targets (i.e., a "treat and forget" approach).[50] For patients ages ≥50 years with CKD category G3 or G4, ezetimibe can be added to simvastatin.[51]

- Statin therapy has been associated with liver dysfunction and myopathy and should be monitored in patients with CKD.

### adjunct additional antihypertensive therapy

Treatment recommended for SOME patients in selected patient group

#### Primary options

| OR
| chlorthalidone: 12.5 to 25 mg orally once daily initially, adjust dose gradually according to response, maximum 50 mg/day
| OR
| hydrochlorothiazide: 12.5 mg orally once daily initially, adjust dose gradually according to response, maximum 50 mg/day

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### Acute

- **atenolol**: 25 mg orally once daily initially, adjust dose gradually according to response, maximum 25-50 mg/day

- **metoprolol succinate**: 25 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 100 mg/day

- **nifedipine**: 30-60 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 90 mg/day (120 mg/day for some brands)

- **amlodipine**: 5 mg orally once daily initially, adjust dose gradually according to response, maximum 10 mg/day

- **felodipine**: 2.5 mg orally once daily initially, adjust dose gradually according to response, maximum 20 mg/day

- **spironolactone**: 12.5 mg orally once daily initially, adjust dose gradually according to response, maximum 200 mg/day given in 2-4 divided doses

### Secondary options

- **hydralazine**: 10 mg orally three to four times daily initially, adjust dose gradually according to response, maximum 300 mg/day

- **minoxidil**: 5 mg orally once daily initially, adjust dose gradually according to response, maximum 40 mg/day
**Acute**

- **clonidine**: 0.1 mg orally (immediate-release) twice daily initially, adjust dose gradually according to response, maximum 0.6 mg/day

- Other classes of antihypertensive agents (e.g., thiazide, or thiazide-like diuretics, beta-blockers, etc.) should be added when the target blood pressure is not achieved with the use of an ACE inhibitor or angiotensin-II receptor antagonist. Aliskiren is not recommended for use in combination with ACE inhibitors or angiotensin-II receptor antagonists.

**Adjunct glycemic control**

Treatment recommended for SOME patients in selected patient group

- In patients with diabetes, glycemic goals should be individualized. For many patients, the goal of HbA1c <7% is appropriate. However, HbA1c 7.0% to 7.9% may be more appropriate in some patients, such as those with advanced age, limited life expectancy, known cardiovascular disease, high risk of severe hypoglycemia, or difficulty achieving lower HbA1c goals despite the use of multiple antihyperglycemic medications and insulin.\(^{[53]}\)

  In patients with diabetes and CKD, there is a risk for hypoglycemia because of impaired kidney clearance of medications, such as insulin (two-thirds of insulin is degraded by the kidney) or sulfonylureas, and because of impaired kidney gluconeogenesis.

- Patients with type 1 diabetes require treatment with insulin, regardless of whether they are on dialysis or not.

- Some specific antihyperglycemic medications significantly reduce all-cause or cardiovascular mortality, or major cardiovascular events or renal complications in some patient subgroups, and may be considered independently of HbA1c targets.\(^{[54]}\)\(^{[55]}\)\(^{[56]}\) Among the antihyperglycemic medications that reduce cardiovascular mortality in some patient subgroups are metformin, sodium-glucose co-transporter 2 (SGLT2) inhibitors (empagliflozin, canagliflozin), and glucagon-like peptide-1 (GLP-1) agonists (liraglutide).\(^{[57]}\)\(^{[58]}\)\(^{[55]}\)\(^{[59]}\)

  There is evidence that the use of SGLT2 inhibitors prevents major kidney outcomes (e.g., dialysis, transplantation, or death due to kidney disease) in people with type 2 diabetes.\(^{[60]}\) SGLT2 inhibitors, in addition to reducing hyperglycemia, have renal benefits through independent effects on renal tubular
Chronic kidney disease

Treatment

### Acute

- glucose reabsorption, weight, blood pressure, intraglomerular pressure, albuminuria, and slowed glomerular filtration rate loss.\[^{[61]}\] \[^{[62]}\]
- The use of SGLT2 inhibitors is not generally recommended in patients with an eGFR of <45 mL/min/1.73 m\(^2\) (<60 mL/min/1.73 m\(^2\) for ertugliflozin); however, the CREDENCE trial included patients with an eGFR 30 to 90 mL/min/1.73 m\(^2\) and demonstrated a decreased risk of kidney failure and cardiovascular events.\[^{[63]}\]
- Use of SGLT2 inhibitors is contraindicated in patients with an eGFR of <30 mL/min/1.73 m\(^2\), including patients with end-stage renal disease who are on dialysis.

- As a class of drugs, GLP-1 agonists have beneficial effects on cardiovascular, mortality, and kidney outcomes in patients with type 2 diabetes.\[^{[64]}\]
- Experience with GLP-1 agonists in patients with renal dysfunction is limited; therefore, these agents should be used with caution.\[^{[65]}\]
- Liraglutide, albiglutide, dulaglutide, and semaglutide are not renally excreted and are the preferred agents in this class. Studies report that dipeptidyl peptidase-4 (DPP-4) inhibitors are renoprotective, but did not have a cardiovascular benefit.\[^{[66]}\] \[^{[67]}\]
- Some DPP-4 inhibitors require dose adjustment in renal impairment.

### Adjunct education about renal replacement therapy

- Treatment recommended for SOME patients in selected patient group
- Patients need to be educated about renal replacement therapy such as hemodialysis, peritoneal dialysis, and kidney transplantation. Patient preference, family support, underlying comorbid conditions, and proximity to a dialysis facility should be addressed when choosing a modality or consideration for palliative care. All patients should undergo CKD education for modality choice.\[^{[87]}\]
- Patients should be referred to surgery for dialysis access and/or evaluated for kidney transplantation, based on patient preference for renal replacement modality at GFR category G4.
- All patients who are proceeding with hemodialysis should be educated on vein preservation with limiting venipuncture and intravenous access to the access arm.\[^{[102]}\]
- Kidney transplantation is indicated once the estimated GFR is <20 mL/minute and the patient...
Chronic kidney disease

Treatment

Acute

has been evaluated and undergone the required testing process by a transplant team.

2nd

nondihydropyridine calcium-channel blocker

Primary options

» diltiazem: 120 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 360 mg/day

OR

» verapamil: 120 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 360 mg/day

» ACE inhibitors and angiotensin-II receptor antagonists are the superior treatment for patients with CKD.

» If these medications need to be discontinued due to adverse effects such as cough, angioedema, hemodynamic decline in renal function, and/or hyperkalemia, then nondihydropyridine calcium-channel blockers have been demonstrated to have more proteinuric-lowering effects than other antihypertensive agents.[112]

plus statin ± ezetimibe

Treatment recommended for ALL patients in selected patient group

Primary options

» simvastatin: 20-40 mg orally once daily

OR

» pravastatin: 40 mg orally once daily

OR

» rosuvastatin: 5-10 mg orally once daily

OR

» atorvastatin: 10-20 mg orally once daily

OR

» ezetimibe/simvastatin: 10 mg (ezetimibe)/20 mg (simvastatin) orally once daily
**Acute**

> Statin therapy has been shown to have cardioprotective effects in patients with CKD.\(^7^9\) [80] [81] [82] In those individuals not on dialysis therapy, the use of statins in a large meta-analysis resulted in the reduction of all-cause mortality by 21% (relative risk [RR] 0.79, 95% CI 0.69 to 0.91) and cardiovascular mortality by 23% (RR 0.77, 95% CI 0.69 to 0.87).\(^8^3\)

> Total cholesterol and low-density lipoprotein treatment targets for patients with CKD have not been well established in clinical trials. As such, the Kidney Disease: Improving Global Outcomes guidelines recommend that GFR category G3 or G4 CKD patients not on dialysis should be treated with a statin without the need for routine follow-up to check lipid values, or to change medication dose regimens based on set targets (i.e., a "treat and forget" approach).\(^5^0\)

For patients ages ≥50 years with CKD GFR category G3 or G4, ezetimibe can be added to simvastatin.\(^5^1\)

> Statin therapy has been associated with liver dysfunction and myopathy and should be monitored in patients with CKD.

<table>
<thead>
<tr>
<th>adjunct</th>
<th>additional antihypertensive therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment recommended for SOME patients in selected patient group</td>
</tr>
</tbody>
</table>

**Primary options**

- **chlorthalidone**: 12.5 to 25 mg orally once daily initially, adjust dose gradually according to response, maximum 50 mg/day
  
  OR

- **hydrochlorothiazide**: 12.5 mg orally once daily initially, adjust dose gradually according to response, maximum 50 mg/day
  
  OR

- **atenolol**: 25 mg orally once daily initially, adjust dose gradually according to response, maximum 25-50 mg/day
  
  OR

- **metoprolol succinate**: 25 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 100 mg/day
  
  OR
### Acute

- **nifedipine**: 30-60 mg orally (extended-release) once daily initially, adjust dose gradually according to response, maximum 90 mg/day (120 mg/day for some brands)

  OR

- **amlodipine**: 5 mg orally once daily initially, adjust dose gradually according to response, maximum 10 mg/day

  OR

- **felodipine**: 2.5 mg orally once daily initially, adjust dose gradually according to response, maximum 20 mg/day

  OR

- **spironolactone**: 12.5 mg orally once daily initially, adjust dose gradually according to response, maximum 200 mg/day given in 2-4 divided doses

  OR

- **aliskiren**: 150 mg orally once daily initially, adjust dose gradually according to response, maximum 300 mg/day

**Secondary options**

- **hydralazine**: 10 mg orally three to four times daily initially, adjust dose gradually according to response, maximum 300 mg/day

  OR

- **minoxidil**: 5 mg orally once daily initially, adjust dose gradually according to response, maximum 40 mg/day

  OR

- **clonidine**: 0.1 mg orally (immediate-release) twice daily initially, adjust dose gradually according to response, maximum 0.6 mg/day

**Other classes of antihypertensive agents** (e.g., thiazide, or thiazide-like diuretics, beta-blockers, etc.) should be added when the target blood pressure is not achieved with the use of a nondihydropyridine calcium-channel blocker.
### Acute

<table>
<thead>
<tr>
<th><strong>adjunct</strong></th>
<th><strong>glycemic control</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment recommended for SOME patients in selected patient group</td>
<td></td>
</tr>
</tbody>
</table>
  - In patients with diabetes, glycemic goals should be individualized. For many patients, the goal of HbA1c <7% is appropriate. However, HbA1c 7.0% to 7.9% may be more appropriate in some patients, such as those with advanced age, limited life expectancy, known cardiovascular disease, high risk of severe hypoglycemia, or difficulty achieving lower HbA1c goals despite the use of multiple antihyperglycemic medications and insulin. [53]
  - In patients with diabetes and CKD, there is a risk for hypoglycemia because of impaired kidney clearance of medications, such as insulin (two-thirds of insulin is degraded by the kidney) or sulfonylureas, and because of impaired kidney gluconeogenesis.
  - Patients with type 1 diabetes require treatment with insulin, regardless of whether they are on dialysis or not.
  - Some specific antihyperglycemic medications significantly reduce all-cause or cardiovascular mortality, or major cardiovascular events or renal complications in some patient subgroups, and may be considered independently of HbA1c targets. [54] [55] [56] Among the antihyperglycemic medications that reduce cardiovascular mortality in some patient subgroups are metformin, sodium-glucose co-transporter 2 (SGLT2) inhibitors (empagliflozin, canagliflozin), and glucagon-like peptide-1 (GLP-1) agonists (liraglutide). [57] [58] [55] [59]
  - There is evidence that the use of SGLT2 inhibitors prevents major kidney outcomes (e.g., dialysis, transplantation, or death due to kidney disease) in people with type 2 diabetes. [60] SGLT2 inhibitors, in addition to reducing hyperglycemia, have renal benefits through independent effects on renal tubular glucose reabsorption, weight, blood pressure, intraglomerular pressure, albuminuria, and slowed GFR loss. [61] [62] The use of SGLT2 inhibitors is not generally recommended in patients with an estimated (eGFR) of <45 mL/min/1.73 m² (<60 mL/min/1.73 m² for ertugliflozin); however, the CREDENCE trial included patients with an eGFR 30 to 90 mL/min/1.73 m² and demonstrated a decreased risk of kidney failure and cardiovascular events. [63] Use of SGLT2 inhibitors is contraindicated in patients with an eGFR of <30 mL/min/1.73 m²,
### Chronic kidney disease

#### Treatment

<table>
<thead>
<tr>
<th>Acute</th>
<th></th>
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</table>
| **including patients with end-stage renal disease who are on dialysis.**<br>» As a class of drugs, GLP-1 agonists have beneficial effects on cardiovascular, mortality, and kidney outcomes in patients with type 2 diabetes.[64] Experience with GLP-1 agonists in patients with renal dysfunction is limited; therefore, these agents should be used with caution.[65] Liraglutide, albiglutide, dulaglutide, and semaglutide are not renally excreted and are the preferred agents in this class.<br>» Studies report that dipeptidyl peptidase-4 (DPP-4) inhibitors are renoprotective, but did not have a cardiovascular benefit.[66] [67] Some DPP-4 inhibitors require dose adjustment in renal impairment. | **adjunct education about renal replacement therapy**<br>Treatment recommended for SOME patients in selected patient group<br>» Patients need to be educated about renal replacement therapy such as hemodialysis, peritoneal dialysis, and kidney transplantation. Patient preference, family support, underlying comorbid conditions, and proximity to a dialysis facility should be addressed when choosing a modality or consideration for palliative care. All patients should undergo CKD education for modality choice.[87]<br>» Patients should be referred to surgery for dialysis access and/or evaluated for kidney transplantation, based on patient preference for renal replacement modality at GFR category G4.<br>» All patients who are proceeding with hemodialysis should be educated on vein preservation with limiting venipuncture and intravenous access to the access arm.[102]<br>» Kidney transplantation is indicated once the estimated GFR is <20 mL/minute and the patient has been evaluated and undergone the required testing process by a transplant team. | **with anemia**<br>adjunct **erythropoietin-stimulating agent**<br>Treatment recommended for SOME patients in selected patient group<br>**Primary options**<br>» *epoetin alfa*: consult specialist for guidance on dose
Chronic kidney disease

Treatment

<table>
<thead>
<tr>
<th>Acute</th>
<th>OR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>» <strong>darbepoetin alfa</strong>: consult specialist for guidance on dose</td>
</tr>
<tr>
<td></td>
<td>» When GFR category G3a/G3b has been reached, identification of comorbidities such as anemia is recommended and treatment begun if required. Treatment of anemia with the use of erythropoietin-stimulating agents is recommended for patients with CKD after other causes of anemia such as iron, vitamin B12, folate, or blood loss have been excluded. Due to the possibility of an increased risk of stroke in those on erythropoietin-stimulating agents, discussion between the patient and physician should ensue prior to treatment initiation. [91] [93] [94] [95]</td>
</tr>
<tr>
<td></td>
<td>» Erythropoietin-stimulating agents are initiated once the hemoglobin (Hb) falls to &lt;10 g/dL and the patient has signs and symptoms of anemia.</td>
</tr>
<tr>
<td></td>
<td>» The target Hb for patients with CKD on erythropoietin therapy is 10-11 g/dL, as normalization of Hb has resulted in increased risk for death and cardiovascular disease in this population. [89] [90]</td>
</tr>
<tr>
<td></td>
<td>» Peginesatide was withdrawn from the market in early 2013 due to postmarketing reports of serious and fatal hypersensitivity reactions. Therefore, it is no longer recommended.</td>
</tr>
</tbody>
</table>

**adjunct iron**

Treatment recommended for SOME patients in selected patient group

**Primary options**

- **ferrous sulfate**: 60 mg orally once to three times daily
  Dose refers to elemental iron.

  OR

- **ferrous gluconate**: 60 mg orally once to three times daily
  Dose refers to elemental iron.

**Secondary options**

- **sodium ferric gluconate complex**: consult specialist for guidance on dose

  OR
### Chronic kidney disease

#### Treatment

**Acute**

- **» iron sucrose**: consult specialist for guidance on dose

**OR**

- **» ferumoxytol**: consult specialist for guidance on dose

**OR**

- **» ferric carboxymaltose**: consult specialist for guidance on dose

- **» All patients should have an evaluation of iron stores if erythropoietin therapy is planned. The goal ferritin for those not on hemodialysis is >100 nanograms/mL, while for those on hemodialysis is >200 nanograms/mL. All patients should have a transferrin saturation >20%. Iron replacement can be given orally or parenterally.**[113] [96]

---

#### with secondary hyperparathyroidism **plus**

dietary modification ± phosphate-binding drug

Treatment recommended for ALL patients in selected patient group

**Primary options**

- **» sevelamer**: 800-1600 mg orally three times daily initially, titrate according to serum phosphate level

**OR**

- **» calcium acetate**: 1334 mg orally with each meal initially, titrate according to serum phosphate level

**OR**

- **» calcium carbonate**: 1-2 g/day orally given in 3-4 divided doses

**OR**

- **» lanthanum**: 500-1000 mg orally three times daily initially, titrate according to serum phosphate level

**OR**

- **» sucroferric oxyhydroxide**: 500 mg orally three times daily initially, titrate according to serum phosphate level, maximum 3000 mg/day
### Acute

» When GFR category G3a/G3b has been reached, identification of comorbidities such as secondary hyperparathyroidism is recommended and treatment begun if required. The calcium and phosphorus levels should be maintained in the normal range with dietary restriction and/or phosphate-binding medications.

» Phosphate binders should be initiated to normalize phosphorus levels if patients are unable to sufficiently restrict phosphorus in the diet.[97] Calcium-based phosphate binders should be restricted if there is associated hypercalcemia, arterial calcification, suppressed parathyroid hormone (PTH), or adynamic bone disease.[97]

» Calcium, phosphorus, and PTH testing should be performed every 6 to 12 months for patients with GFR category G3a/G3b CKD and secondary hyperparathyroidism. For patients with GFR category G4 CKD and secondary hyperparathyroidism, calcium and phosphate should be checked every 3 to 6 months, and PTH every 6 to 12 months.[97] [Evidence C]

» There is limited evidence that dietary restriction in calcium and phosphorus affects renal osteodystrophy.[114]

» There is emerging evidence that the use of noncalcium-based phosphate binders has a survival advantage over calcium-based phosphate binders in patients with CKD.[97] [99] [Evidence B]

<table>
<thead>
<tr>
<th>Adjunct</th>
<th>Adjunct</th>
</tr>
</thead>
<tbody>
<tr>
<td>ergocalciferol</td>
<td>Treatment recommended for SOME patients in selected patient group</td>
</tr>
<tr>
<td>Primary options</td>
<td></td>
</tr>
<tr>
<td>» ergocalciferol (vitamin D2): dose depends on serum 25-OH vitamin D level; consult specialist for guidance on dose</td>
<td></td>
</tr>
<tr>
<td>» It is recommended to exclude concomitant 25-OH vitamin D deficiency and prescribe 25, dihydroxyvitamin D if &lt;30 nanograms/dL.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adjunct</th>
<th>Adjunct</th>
</tr>
</thead>
<tbody>
<tr>
<td>active vitamin D analog</td>
<td>Treatment recommended for SOME patients in selected patient group</td>
</tr>
<tr>
<td>Primary options</td>
<td></td>
</tr>
<tr>
<td>» calcitriol: consult specialist for guidance on dose</td>
<td></td>
</tr>
</tbody>
</table>
### Chronic kidney disease

#### Treatment

<table>
<thead>
<tr>
<th>Acute</th>
<th>GFR category G5 or with uremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>with metabolic acidosis</td>
<td><strong>adjunct</strong> oral sodium bicarbonate</td>
</tr>
<tr>
<td>Treatment recommended for SOME patients in selected patient group</td>
<td></td>
</tr>
<tr>
<td><strong>Primary options</strong></td>
<td><strong>Primary options</strong></td>
</tr>
<tr>
<td>» sodium bicarbonate: consult specialist for guidance on dose</td>
<td>» Renal replacement therapy is initiated once patients have GFR category G5 disease and/or signs of uremia such as weight loss, lack of appetite, nausea, vomiting, acidosis, hyperkalemia, or fluid overload. [1]</td>
</tr>
<tr>
<td>» For patients who develop metabolic acidosis, supplementation with oral sodium bicarbonate to a target serum bicarbonate level of &gt;20 mEq/L has been shown to slow progression of CKD and improve nutritional parameters. Oral sodium bicarbonate is well tolerated in this group. [103]</td>
<td>» Renal replacement therapy in the form of dialysis is designed to remove toxic waste products from the blood, such as urea, and normalise potassium and serum bicarbonate levels, as well as to remove fluid that will accumulate once the kidneys have failed.</td>
</tr>
<tr>
<td>» All patients should undergo CKD education for modality choice. [87]</td>
<td>» Peritoneal dialysis is performed at home and is available to all patients. A peritoneal dialysis catheter is inserted into the abdomen and dialysis fluid is instilled in order to allow for</td>
</tr>
<tr>
<td>» paricalcitol: consult specialist for guidance on dose</td>
<td>» Paricalcitol is a vitamin D analog that is used to reduce the level of parathyroid hormone in the blood. It is effective in treating hyperparathyroidism, a condition in which the parathyroid glands produce too much parathyroid hormone.</td>
</tr>
</tbody>
</table>
### Chronic kidney disease

#### Treatment

**Acute**

- Toxic waste products and fluid to be removed and drained from the body on a daily basis.
  - Continuous cycling peritoneal dialysis is done with a machine at night on a daily basis.
  - Continuous ambulatory peritoneal dialysis is done on a daily basis. Patients manually exchange the peritoneal fluid.
  - Hemodialysis is usually prescribed in a treatment center 3 times a week for approximately 4 hours each session. Hemodialysis can also be carried out at home, usually 4 to 5 days a week, 3 to 4 hours a day. The patient's blood is removed from the body through an arteriovenous fistula, an arteriovenous graft, or a dialysis catheter, and then returned after traversing a dialysis membrane and dialysis solution. Other dialysis options include short daily dialysis and nocturnal dialysis, which are available at some treatment centers.

**with secondary hyperparathyroidism plus dietary modification ± phosphate-binding drug**

Treatment recommended for ALL patients in selected patient group

**Primary options**

- **sevelamer:** 800-1600 mg orally three times daily initially, titrate according to serum phosphate level
  - OR
  - **calcium acetate:** 1334 mg orally with each meal initially, titrate according to serum phosphate level
  - OR
  - **calcium carbonate:** 1-2 g/day orally given in 3-4 divided doses
  - OR
  - **lanthanum:** 500-1000 mg orally three times daily initially, titrate according to serum phosphate level
  - OR
  - **sucroferric oxyhydroxide:** 500 mg orally three times daily initially, titrate according to...
Acute serum phosphate level, maximum 3000 mg/day

» For patients with GFR category G5 CKD on dialysis, calcium, phosphorus, and intact parathyroid hormone (PTH) levels should be managed with phosphate binding agents, calcimimetics, active vitamin D analogs, or a combination of these based on serial laboratory assessments.

» Phosphate binders such as calcium, lanthanum, and sevelamer should be initiated to normalize phosphorus levels if patients are unable to sufficiently restrict phosphorus in the diet.[97] Calcium-based phosphate binders should be restricted if there is associated hypercalcemia, arterial calcification, suppressed PTH, or adynamic bone disease.[97]

» Increasing dialytic phosphate removal may be required in cases of persistent hyperphosphatemia.

» Calcium and phosphorus testing every 1 to 3 months and PTH testing every 3 to 6 months should be performed for patients with GFR category G5 CKD and secondary hyperparathyroidism.[97] [Evidence C]

adjunct calcimimetic ± active vitamin D analog

Treatment recommended for SOME patients in selected patient group

Primary options

» cinacalcet: 30 mg orally once daily initially, increase dose according to serum PTH level, maximum 180 mg/day

--AND/OR--

» calcitriol: consult specialist for guidance on dose
- or -

» paricalcitol: consult specialist for guidance on dose
- or -

» doxercalciferol: consult specialist for guidance on dose

Secondary options

» etelcalcetide: adults: 5 mg intravenously three times weekly at the end of hemodialysis treatment, adjust dose according to PTH level and corrected serum calcium response, maintenance dose ranges from 2.5 to 15 mg three times weekly
### Acute

<table>
<thead>
<tr>
<th>AND/OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>calcitriol: consult specialist for guidance on dose</td>
</tr>
<tr>
<td>or-</td>
</tr>
<tr>
<td>paricalcitol: consult specialist for guidance on dose</td>
</tr>
<tr>
<td>or-</td>
</tr>
<tr>
<td>doxercalciferol: consult specialist for guidance on dose</td>
</tr>
</tbody>
</table>

For those requiring parathyroid hormone (PTH)-lowering therapy, calcimimetics (e.g., cinacalcet, etelcalcetide), active vitamin D analogs (e.g., calcitriol, paricalcitol, doxercalciferol), or a combination of a calcimimetic with an active vitamin D analog should be given.[97]

Etelcalcetide is a second-generation, type II calcimimetic that may be used when treatment with a calcimimetic is indicated but cinacalcet is not a suitable option. It is given intravenously (rather than orally like cinacalcet) and has a longer half-life than cinacalcet.

---

### Adjunct ergocalciferol

Treatment recommended for SOME patients in selected patient group

**Primary options**

- ergocalciferol (vitamin D2): dose depends on serum 25-OH vitamin D level; consult specialist for guidance on dose

It is recommended to exclude concomitant 25-OH vitamin D deficiency and prescribe 25, dihydroxyvitamin D if <30 nanograms/dL.

---

### 2nd kidney transplant

Kidney transplant confers a significant survival advantage over maintenance dialysis therapy, predominantly due to a decrease in the risk of cardiovascular death. All patients who are on dialysis therapy are potentially eligible for kidney transplantation. A transplant center including a nephrologist and transplant surgeon will determine the final eligibility and status of the patient for kidney transplantation, after a complete medical history and evaluation. Kidneys may be transplanted from deceased or living donors.
Emerging

Novel therapies for CKD

Currently, there are many novel agents that are being investigated to slow progression of CKD. Most studies have focused on diabetic kidney disease; however, there are small clinical trials suggesting benefit of some agents in nondiabetic kidney disease. Antifibrotic agents such as tranilast have been shown to reduce the decline in kidney function and proteinuria; however, there has been concern for adverse hepatic and renal effects when used at higher doses in cardiology trials.[115] Agents targeting glycosaminoglycan metabolism such as sulodexide, inhibitors of advanced glycation end products, and anti-inflammatory agents such as pentoxifylline have all demonstrated short-term effects in proteinuria reduction.[115] [116] [117] [118] How these agents will perform in large-scale randomized clinical trials remains to be seen. As of now, there are no novel approved therapies for the treatment of CKD.

Roxadustat

Roxadustat is an oral inhibitor of hypoxia-inducible factor (HIF) prolyl hydroxylase that stimulates erythropoiesis and regulates iron metabolism. It shows promise as an alternative to epoetin alfa as a therapy for anemia in patients with CKD. It is currently in phase III clinical trials.[119] [120]

Veverimer

Veverimer is a nonabsorbed polymer which selectively binds and removes hydrochloric acid from the gastrointestinal lumen and is being investigated for the treatment of metabolic acidosis in patients with CKD. It has been shown to significantly increase serum bicarbonate concentration, with minimal adverse effects. The Food and Drug Administration is currently reviewing an application for approval.[121] [122]
Recommnedations

Monitoring

Patients with risk factors for CKD, such as diabetes, hypertension, or a family member with CKD, should be evaluated annually with serum creatinine and mathematical formulation for estimation of the glomerular filtration rate in addition to urinalysis for hematuria and/or proteinuria.

For those with established CKD, the rate of progression of CKD should be serially assessed starting in glomerular filtration rate (GFR) category G3a/G3b disease. Patients should be screened for anemia and bone mineral disorders at least every 6 to 12 months with a hemoglobin, calcium, phosphorus, and intact parathyroid hormone (PTH). For those in GFR category G4 disease, hemoglobin, calcium, phosphorus should be monitored every 3 to 6 months and intact PTH every 6 to 12 months. For patients in GFR category G5 CKD, anemia should be evaluated with a monthly hemoglobin, and bone mineral disease with a calcium and phosphorus every 1 to 3 months and an intact PTH every 3 to 6 months. Lipids should be checked annually for all patients with CKD.

Patient instructions

Patients with CKD need to take an active role in managing their disease and monitoring their progression to more advanced stages such as glomerular filtration rate (GFR) category G4 to G5. Dietary therapy such as restriction of potassium, phosphorus and salt, protein, and fluids is typically advocated for GFR category G3 to G5. Lifestyle changes that would include medical compliance, optimization of glycemic control, and blood pressure control are the leading factors that delay progression of CKD and the need for renal replacement therapy. As patients enter GFR category G4 CKD, it is recommended that they attend educational classes at a CKD clinic where different dialysis modalities such as hemodialysis and peritoneal dialysis are discussed, to determine their option of choice. Also, patients may be evaluated for kidney transplantation and referred to a transplant center at this time. Once a patient has been educated and the dialysis modality has been chosen, referral for surgery may be done for dialysis access placement.
### Complications

<table>
<thead>
<tr>
<th>Complications</th>
<th>Timeframe</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>anemia</td>
<td>long term</td>
<td>high</td>
</tr>
</tbody>
</table>

Anemia of chronic kidney disease is due to a deficiency of erythropoietin as the glomerular filtration rate (GFR) declines.

Anemia is typically identified in GFR category G3a/G3b CKD. Patients should be screened with a complete blood count at least every 6 to 12 months, and an erythropoietin-stimulating agent may be considered once hemoglobin (Hb) falls to <10 g/dL and there are symptoms of anemia. The target Hb is 10 to 11 g/dL.[91] [93] [125]

If the patient is iron-deficient, oral or intravenous supplementation may also be prescribed.[96]

Patients with CKD on erythropoietin-stimulating agents for the treatment of anemia have a higher risk of death and cardiovascular complications if the Hb is normalized >13 g/dL.[90] [126] [127] [128] [129]

<table>
<thead>
<tr>
<th>renal osteodystrophy</th>
<th>long term</th>
<th>high</th>
</tr>
</thead>
</table>

May be caused by an elevation in parathyroid hormone (PTH) as a result of phosphorus retention and hypocalcemia from 1,25 vitamin D deficiency as the glomerular filtration rate (GFR) declines. Severe hyperparathyroidism and hyperphosphatemia are risk factors for death, cardiovascular disease, and vascular calcification in patients with CKD.[97] [Evidence C]

Patients with GFR category G3 to G5 CKD should be routinely monitored for hyperparathyroidism and treatments based on serial assessments of phosphorus, calcium, and PTH levels, considered together.[97]

25-dihydroxyvitamin D should be monitored and treated if the level is <30 nanograms/L.[130] [131]

<table>
<thead>
<tr>
<th>cardiovascular disease</th>
<th>long term</th>
<th>high</th>
</tr>
</thead>
</table>

CKD is a risk factor for cardiovascular disease, independent of comorbidities such as diabetes, hypertension, and dyslipidemia. Cardiovascular disease is the leading cause of death for these patients, and the overwhelming majority of patients with CKD will die prior to reaching the need for renal replacement therapy.

The goal in treatment of cardiovascular disease in patients with CKD is early recognition and risk factor modification, including lipid therapy, optimization of blood pressure and glycemic control, tobacco cessation, and aspirin use.[133] [134]

<table>
<thead>
<tr>
<th>protein malnutrition</th>
<th>variable</th>
<th>medium</th>
</tr>
</thead>
</table>

As the glomerular filtration rate falls, patients develop anorexia, nausea, vomiting, and lack of protein intake. Previously, patients with advanced CKD were placed on low-protein diets, but this recommendation has limitations due to its worsening of malnutrition. It is recommended for patients with CKD to have 0.6 g/kg protein intake daily and those with nephrotic syndrome 0.8 g/kg protein intake daily, to account for protein losses in the urine. If patients are not able to maintain nutrition, then initiation of renal replacement therapy may be warranted.[132]

<table>
<thead>
<tr>
<th>metabolic acidosis</th>
<th>variable</th>
<th>medium</th>
</tr>
</thead>
</table>

Metabolic acidosis is common in patients with CKD, due to the inability of the kidney to excrete acid once the estimated glomerular filtration rate is <50 mL/minute. The anion gap is typically normal but may be...
Complications | Timeframe | Likelihood
--- | --- | ---
increased in uremia with retention of phosphate anions. Rarely does the serum bicarbonate level fall below 12 mEq/L. Metabolic acidosis may worsen renal osteodystrophy and cause malnutrition, hypercatabolism, and growth retardation.

Treatment involves the administration of sodium bicarbonate 0.5 to 1.0 mEq/kg/day for a target serum bicarbonate level >20 mEq/L. Sodium citrate as a bicarbonate source is generally avoided in patients with CKD, as it increases the absorption of aluminum and may contribute to bone disease and dementia.[135][136]

| hyperkalemia | variable | medium |

Hyperkalemia is common in patients with CKD, due to the kidney's inability to excrete potassium from the diet as the estimated glomerular filtration rate declines. Hyperkalemia is more common in patients with oliguria, resistant or deficient aldosterone state, or coexisting metabolic acidosis. Most patients with hyperkalemia are asymptomatic, but some may present with muscle weakness.

The hallmark for the severity of hyperkalemia is identification of cardiac disturbances on an ECG with peaked T waves, prolongation of the conduction system, sine wave, or asystole. Hyperkalemia associated with cardiac conduction disturbances is a medical emergency and is treated with intravenous calcium; medications to shift potassium into the cells, such as insulin and dextrose; beta-agonists and the focused removal of potassium from the body with loop diuretics, if kidney function is intact; oral potassium binders (e.g., sodium polystyrene sulfonate, patiromer, sodium zirconium cyclosilicate); and, in severe cases, hemodialysis.

| pulmonary edema | variable | medium |

Fluid overload occurs in patients with CKD, especially those with concomitant congestive heart failure. Treatment of fluid overload with loop diuretics is often used to prevent episodes of pulmonary edema and manage peripheral edema. In some instances, a combination diuretic regimen (e.g., a loop and a thiazide diuretic) provides a more effective diuresis in patients. Failure to maintain fluid balance in those with advanced glomerular filtration rate category G4 and G5 CKD is an indication to start renal replacement therapy.

Prognosis

CKD is mostly progressive and leads to end-stage renal disease (ESRD) and the need for renal replacement therapy (i.e., dialysis, transplant). Though it cannot be cured, it can be controlled and managed to a large extent. CKD is a strong cardiovascular risk factor, and the majority of patients with CKD will die prior to reaching ESRD. As kidney function declines, complications such as anemia and hyperparathyroidism develop that may contribute to worsening cardiovascular disease and renal osteodystrophy, respectively. Glycemic control directly correlates with the development of diabetic nephropathy and the rapidity of progression to end-stage renal disease.[111] There is evidence that the use of SGLT2 inhibitors prevents major kidney outcomes (e.g., dialysis, transplantation, or death due to kidney disease) in people with type 2 diabetes.[60] Optimization of blood pressure control with the use of ACE inhibitors or angiotensin-II receptor antagonist agents and reduction in proteinuria may slow the rate of progression to ESRD and the eventual need for renal replacement therapy.

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Diagnostic guidelines

### International

**ACR appropriateness criteria: renal failure** (https://www.acr.org/Clinical-Resources/ACR-Appropriateness-Criteria)  [49]

*Published by:* American College of Radiology  
*Last published:* 2013


*Published by:* Kidney Disease: Improving Global Outcomes  
*Last published:* 2013
# Treatment guidelines

## International


**Published by:** Kidney Disease: Improving Global Outcomes (KDIGO)  
**Last published:** 2017

**KDIGO clinical practice guideline for the evaluation and management of chronic kidney disease** ([https://kdigo.org/guidelines/](https://kdigo.org/guidelines/)) [1]

**Published by:** Kidney Disease: Improving Global Outcomes (KDIGO)  
**Last published:** 2013

**KDIGO clinical practice guideline for lipid management in chronic kidney disease** ([https://kdigo.org/guidelines/](https://kdigo.org/guidelines/)) [50]

**Published by:** Kidney Disease: Improving Global Outcomes (KDIGO)  
**Last published:** 2013

**KDIGO clinical practice guideline for the management of blood pressure in chronic kidney disease** ([https://kdigo.org/guidelines/](https://kdigo.org/guidelines/)) [72]

**Published by:** Kidney Disease: Improving Global Outcomes (KDIGO)  
**Last published:** 2012

**KDIGO clinical practice guideline for anemia in chronic kidney disease** ([https://kdigo.org/guidelines/](https://kdigo.org/guidelines/)) [93]

**Published by:** Kidney Disease: Improving Global Outcomes (KDIGO)  
**Last published:** 2012

**Preservation of peripheral veins in patients with chronic kidney disease** ([https://www.avainfo.org/page/PositionPapers](https://www.avainfo.org/page/PositionPapers)) [102]

**Published by:** Association for Vascular Access  
**Last published:** 2011


**Published by:** Renal Physicians Association  
**Last published:** 2010
**Evidence tables**

What are the effects of calcium-containing phosphate binders versus calcium-free phosphate binders in people with chronic kidney disease-mineral and bone disorder (CKD-MBD)?[97]

This table is a summary of the analysis reported in a guideline (underpinned by a systematic review) that focuses on the above important clinical question.

View the full source guideline (https://kdigo.org/guidelines/ckd-mbd/)

| Evidence B * | Confidence in the evidence is moderate or low to moderate where GRADE has been performed and the intervention may be less effective or likely to be more harmful than the comparison for key outcomes. |

| Population: Pre-dialysis or dialysis adults with hyperphosphatemic CKD a |
| Intervention: Calcium-containing phosphate binders |
| Comparison: Calcium-free phosphate binders |

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Effectiveness (BMJ rating) †</th>
<th>Confidence in evidence (GRADE) ‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>Favors comparison</td>
<td>Moderate</td>
</tr>
<tr>
<td>Cardiovascular and cerebrovascular events</td>
<td>See note b</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Recommendations as stated in the source guideline**
The 2017 Kidney Disease Improving Global Outcomes (KDIGO) guideline on CKD-MBD makes the following recommendation:

In adult patients with CKD (GFR category) G3a–G5D receiving phosphate-lowering treatment, we suggest restricting the dose of calcium-based phosphate binders (weak recommendation; moderate-quality evidence).

**Note**

a Population as reported by the guideline.

b The guideline reported results for this outcome narratively due to inconsistent results across studies. See guideline for more information.
What are the effects of lower versus higher levels of serum phosphate or calcium in people with chronic kidney disease (CKD) G3a-G5 or G5D?[97]

This table is a summary of the analysis reported in a guideline (underpinned by a systematic review) that focuses on the above important clinical question.

View the full source guideline (https://kdigo.org/guidelines/ckd-mbd/)

Evidence C

* Confidence in the evidence is very low or low where GRADE has been performed and the intervention may be more effective/beneficial than the comparison for key outcomes. However, this is uncertain and new evidence could change this in the future.

Population: People with CKD G3a-G5 or G5D

Intervention: Lower concentrations of serum phosphate or calcium

Comparison: Higher concentrations of serum phosphate or calcium

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Effectiveness (BMJ rating)†</th>
<th>Confidence in evidence (GRADE)‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum phosphate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>Favors intervention</td>
<td>Low</td>
</tr>
<tr>
<td>Glomerular Filtration Rate (GFR) decline</td>
<td>See note a</td>
<td>Very Low</td>
</tr>
<tr>
<td>Cardiovascular and cerebrovascular events</td>
<td>See note b</td>
<td>Very Low</td>
</tr>
<tr>
<td>Serum calcium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td>Favors intervention</td>
<td>Low</td>
</tr>
<tr>
<td>Cardiovascular and cerebrovascular events</td>
<td>Favors intervention</td>
<td>Low</td>
</tr>
</tbody>
</table>

Recommendations as stated in the source guideline

The 2017 Kidney Disease Improving Global Outcomes (KDIGO) guideline on CKD-MBD makes the following recommendations:

- In patients with CKD (GFR category) G3a–G5D, treatments of CKD-MBD should be based on serial assessments of phosphate, calcium, and parathyroid hormone (PTH) levels, considered together (not graded).

- In people with CKD G3a-G5D, we suggest lowering elevated phosphate levels toward the normal range (weak recommendation; low-quality evidence).
• In adult patients with CKD G3a–G5D, we suggest avoiding hypercalcemia (weak recommendation; low-quality evidence).

• In patients with CKD G3a–G5D, it is reasonable to base the frequency of monitoring serum calcium, phosphate, and PTH on the presence and magnitude of abnormalities, and the rate of progression of CKD (not graded).c

Note
The guideline only identified evidence from observational studies to answer this clinical question.

a Reported as inconclusive based on indirect evidence from 8 observational studies (N=3755).

b Reported as inconclusive based on direct evidence from 7 observational studies (N=34231).

c The guideline group also recommended reasonable monitoring intervals (not graded). See guideline for more information.

* Evidence levels
The Evidence level is an internal rating applied by BMJ Best Practice. See the EBM Toolkit (https://bestpractice.bmj.com/info/evidence-tables/) for details.

Confidence in evidence
A - High or moderate to high
B - Moderate or low to moderate
C - Very low or low

† Effectiveness (BMJ rating)
Based on statistical significance, which demonstrates that the results are unlikely to be due to chance, but which does not necessarily translate to a clinical significance.

‡ Grade certainty ratings

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>The authors are very confident that the true effect is similar to the estimated effect.</td>
</tr>
<tr>
<td>Moderate</td>
<td>The authors are moderately confident that the true effect is likely to be close to the estimated effect.</td>
</tr>
<tr>
<td>Low</td>
<td>The authors have limited confidence in the effect estimate and the true effect may be substantially different.</td>
</tr>
<tr>
<td>Very Low</td>
<td>The authors have very little confidence in the effect estimate and the true effect is likely to be substantially different.</td>
</tr>
</tbody>
</table>

BMJ Best Practice EBM Toolkit: What is GRADE? (https://bestpractice.bmj.com/info/toolkit/learn-ebm/what-is-grade/)
Key articles


References


Chronic kidney disease

References


Chronic kidney disease


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121. Wesson DE, Mathur V, Tangri N, et al. Veverimer versus placebo in patients with metabolic acidosis associated with chronic kidney disease: a multicentre, randomised, double-blind, controlled,


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Regardless of the language in which the content is displayed, numerals are displayed according to the original English-language numerical separator standard. For example 4 digit numbers shall not include a comma nor a decimal point; numbers of 5 or more digits shall include commas; and numbers stated to be less than 1 shall be depicted using decimal points. See Figure 1 below for an explanatory table.

BMJ accepts no responsibility for misinterpretation of numbers which comply with this stated numerical separator standard.

This approach is in line with the guidance of the International Bureau of Weights and Measures Service.

Figure 1 – BMJ Best Practice Numeral Style
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