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DIAGNOSTIC METHODS FOR CHRONIC KIDNEY DISEASE: A COMPREHENSIVE REVIEW

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Abstract

Chronic kidney disease (CKD) is a global health challenge, characterized by a gradual loss of kidney function over time. Early detection is vital for effective management, yet CKD often remains undiagnosed until advanced stages due to its asymptomatic onset. This review focuses on the key diagnostic methods for CKD, particularly emphasizing serum creatinine, albuminuria, and the albumin-to-creatinine ratio (ACR), which are central to clinical practice. Additionally, advanced imaging, biomarkers, and histological evaluations are discussed. Understanding these diagnostic tools is essential for clinicians to detect CKD early, guide treatment, and mitigate disease progression.

Key words

chronic kidney disease, serum creatinine, albuminuria, albumin-to-creatinine ratio, diagnostic methods.

Introduction

Chronic kidney disease (CKD) is a progressive disorder that affects approximately 10–15% of the global population. Defined by persistent abnormalities in kidney function or structure for over three months, CKD is a significant risk factor for cardiovascular disease, end-stage renal disease (ESRD), and premature mortality. Key risk factors include diabetes, hypertension, obesity, and aging populations.

Early diagnosis of CKD enables timely interventions, including lifestyle modifications, pharmacological treatments, and monitoring to slow progression. Diagnostic methods have evolved significantly, with laboratory tests and imaging

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playing pivotal roles. Among these, serum creatinine, albuminuria, and the albumin-to-creatinine ratio (ACR) remain cornerstone tools. This review explores these methods in detail, alongside complementary diagnostic approaches.

Diagnostic Criteria for CKD

The Kidney Disease: Improving Global Outcomes (KDIGO) guidelines define CKD based on the following criteria:

1. Markers of Kidney Damage: Persistent albuminuria, hematuria, electrolyte abnormalities, or structural abnormalities detected on imaging.

2. Decreased Kidney Function: An estimated glomerular filtration rate (eGFR) of <60 mL/min/1.73 m^2 for at least three months.

These criteria highlight the importance of detecting functional and structural kidney changes through reliable diagnostic methods.

Core Diagnostic Methods

1. Serum Creatinine and Estimated Glomerular Filtration Rate (eGFR).

a. Serum Creatinine

Creatinine, a byproduct of muscle metabolism, is excreted by the kidneys. Elevated serum creatinine levels indicate reduced kidney function.

Principles: Serum creatinine levels inversely correlate with kidney function; as kidney filtration declines, creatinine accumulates in the blood.

Normal Range:

Men: 0.7–1.3 mg/dL

Women: 0.6–1.1 mg/dL

Variations occur due to muscle mass, age, sex, and dietary protein intake.

Limitations:

Serum creatinine alone is insufficient to diagnose CKD, especially in early stages.

Influenced by non-renal factors such as muscle mass, diet, and medications.

b. Estimated Glomerular Filtration Rate (eGFR)

eGFR is calculated using serum creatinine and correction factors for age, sex, and race, with the CKD-EPI equation being the most widely used formula.

Stages of CKD Based on eGFR:

Stage 1: eGFR ≥90 mL/min/1.73 m^2 (with evidence of kidney damage)

Stage 2: eGFR 60–89 mL/min/1.73 m^2

Stage 3a/b: eGFR 30–59 mL/min/1.73 m^2

Stage 4: eGFR 15–29 mL/min/1.73 m^2

Stage 5: eGFR <15 mL/min/1.73 m^2 or on dialysis

Advantages:

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Standardized method for assessing kidney function.

Provides a quantifiable marker for staging CKD.

Limitations:

Less accurate in extreme muscle mass conditions (e.g., athletes, elderly, malnourished).

Ethnic disparities in the eGFR formula (ongoing debates regarding the race adjustment factor).

2. Albuminuria and the Albumin-to-Creatinine Ratio (ACR).

a. Albuminuria

Albuminuria, or the presence of albumin in urine, is a hallmark of kidney damage and an independent risk factor for CKD progression and cardiovascular disease.

Detection Methods:

Urine Dipstick Test: A qualitative, rapid test used for initial screening.

24-hour Urine Collection: Quantifies daily albumin excretion; cumbersome for routine use.

Albuminuria Categories (KDIGO Guidelines):

A1: Normal to mildly increased (<30 mg/g of creatinine)

A2: Moderately increased (30–300 mg/g)

A3: Severely increased (>300 mg/g)

b. Albumin-to-Creatinine Ratio (ACR)

The ACR is the preferred method for detecting albuminuria. Measured in a spot urine sample, it corrects for urine concentration by normalizing albumin levels to creatinine.

Advantages:

High sensitivity and specificity for detecting early kidney damage.

Easier and more reliable than a 24-hour urine collection.

Clinical Relevance:

Elevated ACR is associated with increased risk of CKD progression and cardiovascular events.

ACR testing is recommended annually in high-risk populations (e.g., diabetics, hypertensives).

Limitations:

Variability due to exercise, infection, or menstruation necessitates repeated testing.

3. Urinalysis

Urinalysis provides insights into kidney function and damage.

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Dipstick Test: Screens for proteinuria, hematuria, and specific gravity changes.

Microscopic Examination: Identifies red and white blood cells, casts, and crystals.

Advantages: Low cost and widely available.

Limitations: Less specific than ACR for albumin detection.

Complementary Diagnostic Methods

1. Advanced Imaging

Imaging modalities are crucial for detecting structural abnormalities and complications.

Ultrasound: First-line tool for assessing kidney size, cysts, and obstructions.

CT and MRI: Used for detailed evaluation of renal masses, stones, and vascular abnormalities.

2. Kidney Biopsy.

Biopsy is the gold standard for diagnosing glomerular diseases and systemic conditions affecting the kidney. It is reserved for cases where laboratory and imaging studies are inconclusive.

3. Emerging Biomarkers.

Novel biomarkers, such as cystatin C, NGAL, and KIM-1, are under investigation for improving CKD detection and risk stratification.

Challenges in CKD Diagnosis.

Despite advancements, CKD diagnosis faces challenges:

1. Asymptomatic Early Stages: CKD is often silent in its early phases, leading to delayed diagnosis.

2. Test Variability: Factors such as diet, hydration, and concurrent illnesses can affect diagnostic accuracy.

3. Resource Limitations: Advanced diagnostic tools are not universally available, especially in low-resource settings.

Conclusion

Accurate and timely diagnosis of CKD is essential for effective management and prevention of disease progression. Serum creatinine, eGFR, albuminuria, and the ACR form the cornerstone of CKD diagnostics, offering a balance of reliability and accessibility. Advanced imaging and histological evaluation complement these methods, while novel biomarkers hold promise for refining diagnostic accuracy. Addressing current challenges and improving access to diagnostic tools remain priorities for enhancing global CKD care.

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