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RECENT DEVELOPMENTS IN DIAGNOSTIC AND THERAPEUTIC STRATEGIES FOR CHRONIC KIDNEY DISEASE

Masharipova Zarina

Assistant at Urgench Branch of Tashkent Medical Academy,
department of internal disease at regional hospital of
Khorezm region, Urgench, Uzbekistan.

Abstract: *Chronic kidney disease (CKD) remains a major global health challenge due to its progressive course and strong association with increased morbidity, mortality, and reduced quality of life. This article explores the importance of integrating advanced medical technologies with innovative diagnostic and therapeutic strategies in the comprehensive management of patients with chronic kidney disease. The application of targeted pharmacotherapy, principles of regenerative medicine, and emerging biomarkers has substantially improved early disease detection, risk stratification, and treatment efficacy in CKD populations. Particular emphasis is placed on the contribution of modern diagnostic modalities and personalized therapeutic approaches to improving clinical outcomes, enhancing quality of life, and slowing disease progression. The adoption of state-of-the-art technologies represents a promising direction for optimizing patient-centered care in contemporary nephrology.*

Keywords: *Chronic kidney disease, renal dysfunction, Cystatin C, NGAL, urinary albumin, biomarkers, dialysis, pharmacotherapy, personalized medicine.*

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Introduction

Chronic kidney disease is a progressive and irreversible condition characterized by a sustained decline in renal function and structural kidney damage, regardless of the underlying etiology. CKD represents a significant public health burden worldwide and is associated with high cardiovascular risk, increased hospitalization rates, and premature mortality. Common etiological factors include diabetes mellitus, arterial hypertension, glomerulonephritis, and hereditary renal disorders.

As kidney function deteriorates, patients with CKD develop a wide range of systemic complications, including electrolyte imbalances, anemia, mineral and bone disorders, and cardiovascular disease. Progressive loss of glomerular filtration rate (GFR) leads to the accumulation of uremic toxins and metabolic disturbances, further accelerating disease progression. Despite advances in nephrology, CKD often remains asymptomatic in its early stages, highlighting the need for improved diagnostic tools and early intervention strategies.

Literature Review

Modern Diagnostic Approaches

The introduction of advanced diagnostic technologies has significantly enhanced the assessment of disease stage, progression, and complication risk in chronic kidney disease. Contemporary diagnostic strategies integrate laboratory biomarkers with imaging modalities to achieve early and accurate detection of renal impairment.

Ultrasound-based imaging, magnetic resonance imaging (MRI), and functional renal imaging allow evaluation of kidney size, cortical thickness, perfusion, and structural abnormalities. These techniques support timely identification of disease progression and guide individualized treatment planning.

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Advanced Biomarkers

Emerging biomarkers play a critical role in the early detection and monitoring of renal dysfunction in patients with chronic kidney disease.

Cystatin C has emerged as a reliable and sensitive marker of glomerular filtration, offering superior accuracy compared to serum creatinine, particularly in elderly patients and those with reduced muscle mass. Elevated cystatin C levels are strongly associated with CKD progression and adverse cardiovascular outcomes.

Neutrophil gelatinase-associated lipocalin (NGAL) serves as an early indicator of tubular injury and enables detection of subclinical kidney damage before significant changes in traditional renal function markers occur.

Urinary albumin-to-creatinine ratio (UACR) is a key marker of glomerular damage and endothelial dysfunction, providing prognostic information and assisting in CKD staging and risk stratification.

Modern Imaging Techniques

Advanced imaging modalities contribute to a detailed structural and functional assessment of renal tissue.

Renal ultrasonography allows evaluation of kidney morphology, echogenicity, and obstruction.

Magnetic resonance imaging (MRI) provides high-resolution visualization of renal parenchyma and vascular structures without ionizing radiation.

Doppler ultrasonography is essential for assessing renal blood flow and identifying hemodynamic abnormalities that may contribute to disease progression.

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Research Methodology

Laboratory Assessment

Renal function evaluation in patients with chronic kidney disease involved comprehensive laboratory testing, including serum creatinine, urea, and estimated glomerular filtration rate (eGFR) using standardized equations. The urinary albumin-to-creatinine ratio was used to assess glomerular damage and disease severity. In addition, composite renal indices integrating multiple biomarkers were applied to improve diagnostic precision and guide personalized therapeutic decision-making.

Advances in Pharmacotherapy

Pharmacological management of CKD focuses on slowing disease progression, controlling comorbid conditions, and preventing complications.

Renin–angiotensin–aldosterone system (RAAS) inhibitors remain a cornerstone of therapy due to their nephroprotective effects. Sodium–glucose cotransporter-2 (SGLT2) inhibitors have recently demonstrated significant benefits in reducing CKD progression and cardiovascular risk. Additional pharmacological strategies target inflammation, oxidative stress, and fibrosis to preserve residual renal function.

Ongoing research aims to develop novel therapeutic agents that modulate molecular pathways involved in renal injury and repair.

Innovative Therapeutic Strategies

Advanced treatment options for patients with progressive chronic kidney disease include renal replacement therapies and regenerative approaches.

Dialysis remains the primary life-sustaining therapy for patients with end-stage renal disease. Both hemodialysis and peritoneal dialysis have evolved with technological advancements aimed at improving biocompatibility, efficiency, and patient comfort.

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Kidney transplantation represents the most effective treatment for eligible patients, offering superior survival and quality-of-life outcomes compared to long-term dialysis. However, limited donor availability and immunological challenges remain significant barriers.

Emerging regenerative medicine approaches, including stem cell therapy and bioengineered tissues, hold promise for future CKD treatment.

Results and Analysis

Digitalization and Artificial Intelligence in Nephrology

Digital health technologies and artificial intelligence (AI) are increasingly integrated into CKD management. Machine learning algorithms enable prediction of disease progression, identification of high-risk patients, and optimization of treatment strategies. Wearable devices and remote monitoring systems facilitate continuous assessment of blood pressure, fluid status, and other vital parameters, allowing early detection of clinical deterioration. Telemedicine platforms enhance access to nephrology care, particularly for patients in underserved or remote regions.

Challenges and Future Opportunities

Despite substantial progress, the implementation of advanced technologies in CKD management faces several challenges, including high costs, limited access in low-resource settings, and the need for specialized training of healthcare professionals. Addressing these barriers requires investment in education, infrastructure development, and the creation of cost-effective diagnostic and therapeutic solutions.

Future research should prioritize long-term outcome studies, wider accessibility of innovative technologies, and integration of novel approaches with established clinical guidelines.

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Conclusion

The integration of modern diagnostic tools, innovative biomarkers, and advanced therapeutic strategies has significantly improved the management of chronic kidney disease. Personalized, technology-driven approaches offer considerable potential to enhance clinical outcomes, improve quality of life, and slow disease progression in patients with CKD. Continued research and technological advancement are essential to further optimize nephrology practice and ensure equitable access to high-quality renal care.

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