

## Postprint: Application Practice of Precision Tiered Diagnosis and Treatment for Chronic Kidney Disease (CKD) Management

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### Abstract

**Background** The tiered diagnosis and treatment system represents a crucial step in optimizing the basic medical and health care system. However, its implementation faces obstacles, including inconsistent referral standards, discontinuity across care settings, and temporal delays, which hinder the advancement of the medical consortium model.

**Objective** To select chronic kidney disease (CKD), a regionally prevalent condition, and explore the establishment of a precise tiered diagnosis and treatment system for CKD within medical consortia, with an empirical application evaluation.

**Methods** Using chronic kidney disease (CKD) as a case study, we systematically delineated disease management patterns for CKD patients based on clinical guidelines, established a bidirectional referral knowledge base for CKD featuring interconnected medical information sharing and standardized referral protocols, designed the workflow for a regional CKD-specific tiered diagnosis and treatment information system, and constructed an integrated management model for disease-specific tiered diagnosis and treatment based on hospital-community collaborative management.

**Results** We developed a CKD-specific tiered diagnosis and treatment system that promotes regional medical resource integration and vertical collaboration through information technology support, establishing a disease management system spanning the entire life cycle from early screening, diagnostic alerts, disease-specific treatment to continuous follow-up tracking, along with a vertically collaborative disease-specific management model.

**Conclusion** The disease-specific tiered diagnosis and treatment model based on the CKD knowledge base can precisely identify susceptible and high-risk pop-

ulations, enable timely screening and assessment of early-stage CKD patients, and enhance health management and clinical efficiency for CKD patients.

## Full Text

### Application Practice of Precision Tiered Diagnosis and Treatment Based on Chronic Kidney Disease Management

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## Abstract

**Background:** The tiered diagnosis and treatment system represents a crucial step in optimizing China' s basic medical and healthcare framework, yet its implementation faces significant obstacles. Inconsistent referral standards, spatial discontinuities, and temporal delays have hindered the advancement of medical consortium models. **Objective:** This study selected chronic kidney disease (CKD), a regionally prevalent condition, to explore and establish a precision tiered diagnosis and treatment system for CKD within medical consortiums, conducting empirical application evaluations. **Methods:** Using CKD as a case study, we systematically reviewed disease management protocols based on clinical guidelines, established a two-way referral knowledge base for CKD with integrated medical information sharing and standardized referral criteria, designed regional CKD-specific tiered diagnosis and treatment information system workflows, and constructed an integrated disease management model based on hospital-community collaborative management. **Results:** We developed a CKD-specific tiered diagnosis and treatment system that promotes regional medical resource integration and vertical collaboration through information technology support. This system establishes a disease management framework spanning the entire lifecycle—from early screening and diagnostic alerts to specialized treatment and continuous follow-up—while enabling a vertically integrated disease management model. **Conclusion:** The CKD-specific tiered diagnosis and treatment model based on a CKD knowledge base can accurately identify at-risk and high-risk populations, enable timely screening and evaluation of early-stage CKD patients, and improve health management and clinical efficiency for CKD patients.

**Keywords:** Tiered diagnosis and treatment; Medical consortium; Chronic kidney disease; CKD knowledge base; Health management

## Introduction

The State Council’s “Guiding Opinions on Promoting the Construction of Tiered Diagnosis and Treatment System” (Document No. 70 [2015]) provides important guidance for medical consortium development, marking a shift toward standardized construction in China. This policy aims to gradually implement the tiered diagnosis and treatment model of “primary care first, two-way referral, acute-chronic separation, and vertical collaboration.” Establishing a tiered diagnosis and treatment system is essential for optimizing the basic medical and health-care framework, helping to build a more comprehensive medical service system, advanced service delivery models, and orderly patient flow patterns. Using medical consortiums to address public healthcare access challenges and promote collaboration among healthcare institutions at different levels represents a crucial driver for guiding rational patient utilization.

Chinese provinces and municipalities have implemented tiered diagnosis and treatment according to national policies, adapting them to local conditions with notable achievements, though several challenges persist. These include uneven distribution of medical resources, with high-quality resources concentrated in large hospitals; difficulties in recruiting and retaining excellent physicians at primary care facilities, leading to significant regional disparities; inadequate information sharing among institutions, resulting in fragmented medical data and redundant services; and implementation obstacles stemming from inconsistent referral standards, spatial discontinuities, and temporal delays that hinder medical consortium model advancement.

Given these challenges, tiered diagnosis and treatment represents a critical breakthrough for optimizing regional medical resource allocation and enhancing primary care service capacity. Large and medium-sized hospitals must therefore explore precision tiered diagnosis and treatment models within their regions, select regionally prevalent diseases, optimize patient care pathways, and establish integrated collaboration frameworks among patients, general hospitals, and community facilities.

## 1 Construction of CKD-Specific Tiered Diagnosis and Treatment System

Chronic Kidney Disease (CKD) is a progressive condition characterized by gradual loss of kidney function that has become a major global public health concern and a leading cause of mortality worldwide. In China, CKD prevalence reaches 10.8%, affecting over 140 million individuals, making it a significant threat to public health alongside cardiovascular disease, diabetes, and cancer.

Chronic renal failure at Shanghai Pudong New Area People’s Hospital (hereinafter “Pudong People’s Hospital”) is a key specialty in Pudong New Area. The hospital treats numerous CKD patients and possesses extensive clinical experience in diagnosis, treatment, and prevention. As one of Shanghai’s first regional medical centers, Pudong People’s Hospital has partnered with seven community

health centers to develop an information technology-supported precision tiered diagnosis and treatment management program for CKD within the Chuansha Medical Consortium. This program establishes hierarchical referral alerts and two-way referral workflows through information systems to optimize CKD management efficiency and quality, enabling specialists and general practitioners within the consortium to jointly participate in comprehensive CKD screening, treatment, tracking, and management throughout the disease lifecycle, thereby improving regional CKD prevention and management standards.

**1.1 System Architecture Design** CKD-specific tiered diagnosis and treatment management utilizes information technology tools to integrate, analyze, and process electronic medical record (EMR) data and laboratory reports, enabling precision screening and assessment alerts, and facilitating patient referrals between higher- and lower-level hospitals as well as cross-institutional medical information management. To achieve medical data integration, the CKD management system must interface with EMR, Laboratory Information Systems (LIS), Clinical Decision Support Systems (CDSS), and other platforms across consortium institutions. EMR serves as the core support for daily clinical operations, documenting timely and comprehensive patient medical records; LIS stores and preserves laboratory data with automated alerts for abnormal and critical values to assist physicians in timely clinical judgment; CDSS provides intelligent analytical support for clinical diagnosis, treatment, examination, and nursing decisions. When physicians examine CKD patients within the consortium, the tiered diagnosis and treatment management system requests historical data from LIS and EMR systems, while LIS simultaneously pushes laboratory data to CDSS in real-time, providing data support for CKD-specific tiered diagnosis and treatment.

[Figure 1: see original paper] illustrates the logical architecture of the CKD-specific tiered diagnosis and treatment system, which comprises five layers. The infrastructure layer includes hardware such as two-way referral networks, data storage, and cybersecurity for consortium institutions, centrally deployed using Chuansha Medical Consortium resources. The data layer uniformly processes integrated LIS databases, EMR databases, CDSS knowledge bases, and CKD databases, aggregating patient visit, laboratory, and diagnostic information to enable regional medical data sharing and unified data support for tiered diagnosis and treatment. The service layer standardizes database data into services and establishes open capability interfaces. The business layer further processes aggregated data services, including data standardization and association, CKD rule calculation and judgment, and external information retrieval. The application layer displays tiered diagnosis and treatment assessment results and referral alert messages through the system interface.

**1.2 CKD-Specific Tiered Diagnosis and Treatment Knowledge Base** Establishing a CKD two-way referral knowledge base with integrated medical information sharing and standardized referral rules is fundamental for implement-

ing precision tiered diagnosis and treatment for nephrology within regional medical consortiums. Based on the “Guidelines for Screening, Diagnosis, Prevention and Treatment of Chronic Kidney Disease (2017 Edition)” and evidence-based decision-making models for CKD two-way referral, Pudong People’ s Hospital designed a CKD-specific tiered diagnosis and treatment knowledge base using regional CKD patient visit data. Its primary functional modules include CKD screening and risk assessment, CKD registration, information updates, follow-up, statistical analysis, and referral alerts. The knowledge base standardizes medical terminology for patient history and family genetics, performs standardized data governance on multi-source heterogeneous raw patient data, and forms a high-quality, computable CKD two-way referral knowledge base that provides a unified information source for subsequent data applications.

The CKD-specific tiered diagnosis and treatment knowledge base constructs a CKD management model based on urban-rural resident health record datasets, visit information, CKD-related examination standards, and diagnostic results. It connects information systems across two levels of medical institutions within the regional consortium, accessing and storing data from institutional LIS, CIS, and EMR systems in a service center. Through extraction, synchronization, and aggregation processes, it achieves collection and convergence of multi-hospital, multi-source heterogeneous data. Data serialization and deserialization transform LIS and EMR system tabular data into CDSS rules, forming a relatively complete business rule information database. For governed data, eGFR is calculated using the CKD-EPI equation. Combined with eGFR results, family history of hereditary kidney disease, acute renal failure history, urinary red blood cells, age, and other information, CKD tiered referral rules are established to accurately determine CKD severity and push tiered diagnosis and treatment plans, ensuring scientific treatment protocols and continuity of care while promoting precision tiered diagnosis and treatment within regional medical consortiums.

### 1.3 CKD-Specific Tiered Diagnosis and Treatment System Workflow

Timely and accurate information transmission and integration during two-way referral processes are fundamental to ensuring patient information continuity and critical for delivering continuous, coordinated services. To implement the “1+1+1” medical model and tiered diagnosis and treatment system, Pudong People’ s Hospital accelerated information sharing with lower-level secondary hospitals and community facilities, establishing CKD-specific tiered diagnosis and treatment precision alerts and two-way referral workflows to promote regional medical resource integration and vertical collaboration, as detailed in [Figure 2: see original paper].

**Upward referral** occurs when patients meet upward referral criteria and community physicians submit referral requests through the family doctor workstation system, scheduling referrals via Shanghai’ s tiered diagnosis and treatment system portal. When patients visit community hospitals, physicians activate the CDSS engine to request data, with LIS and CIS systems providing basic patient

information, laboratory data from the past three months, and historical medical records. eGFR is calculated using the CKD-EPI equation. The CKD management model evaluates referral rules: when eGFR meets Referral Rule 1 ( $<15 \text{ ml}/(\text{min} \cdot 1.73\text{m}^2)$ )—patients are classified as extremely high-risk nephropathy, triggering urgent referral alerts to the higher-level hospital nephrology clinic. For Rules 2-7 (), when both eGFR and albuminuria meet specified ranges, referral alerts are triggered requiring community-to-higher-level nephrology clinic referral. Rule 8 () identifies suspected CKD when patients have acute renal failure history with eGFR  $<60 \text{ ml}/(\text{min} \cdot 1.73\text{m}^2)$  or albuminuria A3 (ACR $>300 \text{ mg/g}$ ), triggering community-to-higher-level referral.

**Downward referral** primarily involves patients visiting large or medium-sized hospitals, where physicians activate the CDSS engine to request data from LIS and CIS systems, obtaining basic information, three months of laboratory data, and historical records. eGFR is calculated via CKD-EPI, and the CKD management model evaluates referral rules. For patients meeting downward referral criteria, physicians develop continuous treatment and rehabilitation plans and submit downward referral applications through the two-way referral platform. Rules 1-3 () trigger referrals from higher-level nephrology clinics to community hospitals when eGFR and albuminuria meet specified ranges, enabling CKD health monitoring at community facilities. Rules 4-11 () identify suspected CKD cases, triggering referrals from higher-level nephrology clinics to community hospitals.

## 2 Application Effects

**2.1 Dynamic Management of CKD Patient Health Records: Initial Success in Precision Tiered Diagnosis and Treatment** To evaluate CKD tiered diagnosis and treatment effectiveness, a pilot validation of the integrated CKD management model began in May 2022 within the medical consortium, aggregating examination reports, prescriptions, diagnostic results, hospitalization information, and health screening data from patients visiting different-level institutions. Based on the consortium's CKD-specific tiered diagnosis and treatment knowledge base and integrated patient data sharing, the system accurately screened potential suspected CKD patients, enabling dynamic lifecycle supervision of chronic disease through “two-way referral and vertical collaboration.” For patients with laboratory information within the consortium during the past three months: in July 2022, Pudong People's Hospital nephrology clinic had 426 visits, with the CDSS system identifying 36 suspected patients and 12 medium-low risk patients for downward referral to communities, while confirming 40 cases of renal failure azotemia, uremia, and CKD Stage 5. One community general practice clinic had 385 visits, with the system alerting 12 suspected patients for upward referral to the hospital nephrology clinic.

## 2.2 Promoting Medical Consortium Health Information Platform Construction and Building Medical Data Monitoring and Early

**Warning Mechanisms** Information technology development has accelerated CKD medical consortium construction and facilitated integration of medical resources and data sharing. The Pudong People's Hospital CKD tiered diagnosis and treatment system interfaces with government network data ports, enabling interconnectivity and shared utilization of urban-rural resident health records, prescriptions, EMRs, and examination data across the consortium, thereby improving health information platform construction. For patients requiring downward referral to community hospitals, physicians use the tiered diagnosis and treatment system to precisely push continuous treatment and rehabilitation plans to community facilities, achieving effective medical resource integration. Additionally, the CKD tiered diagnosis and treatment system can preliminarily assess disease severity by combining historical examination data, EMR information, and eGFR results, screening early or suspected patients and delivering preliminary diagnostic alerts to hospitals and patients. This enables resident CKD health monitoring and early warning, guiding patients to appropriate-level medical institutions. Currently, all medical units within the consortium extensively utilize the CDSS monitoring and alert functions, achieving 100% coverage of CKD chronic disease assessment. Compared to previous experience-based manual referral processes, the system-based precision tiered strategy provides more comprehensive, timely, and accurate improvement in CKD patient management efficiency, forming a “monitoring-warning-diagnosis-treatment-rehabilitation-follow-up” lifecycle dynamic supervision model.

**2.3 Rational Planning and Allocation of Regional Medical Resources to Enhance Precision Health Management Service Capacity** Medical consortium leading organizations should coordinate regional planning of personnel, financial, material, and technical resources to establish compact medical consortiums integrating prevention, diagnosis, treatment, rehabilitation, and nursing services in a grid layout. Within the Chuansha Medical Consortium, Pudong People's Hospital has established business cooperation with other medical institutions in ultrasound examinations and hemodialysis, rationally allocating expert and department resources through 下沉 mechanisms, establishing specialist clinics in community hospitals, and organizing department experts for medical technology lectures across the consortium to facilitate rational regional medical resource circulation. By sharing specialist and featured medical services, the consortium provides both “blood transfusion” and “blood production” support to primary care facilities, improving overall diagnostic capacity and equipment utilization efficiency. The tiered diagnosis and treatment system guides medium-low risk and suspected CKD patients to primary care facilities, while regular individual, group, and community activities provide chronic disease, rehabilitation, and health monitoring services for hospitalized and discharged patients and their families. Through follow-up and health education, the system guides CKD patients toward healthy lifestyles, emphasizes psychological support for severe cases, and corrects the public misconception of “treatment over preven-

tion” for CKD, promoting a tiered diagnosis and treatment order of “severe cases upward, rehabilitation downward.”

### 3 Discussion

Tiered diagnosis and treatment is a critical component of chronic disease life-cycle prevention and control. This study focused on CKD management patterns and methods, constructing a CKD-specific tiered diagnosis and treatment knowledge base that deeply integrates with business systems to create practical application scenarios for disease-specific knowledge bases. This approach accurately identifies at-risk and high-risk populations for timely early CKD screening and assessment. On one hand, the model helps determine disease risk levels and establishes a chronic disease management system spanning early screening, diagnostic alerts, specialized treatment, and follow-up tracking, achieving integration of medical technology and services between higher-level hospitals and primary community facilities to create a new integrated management model characterized by “precision management, precision information, and precision services.” On the other hand, several issues emerged during actual project implementation and application.

**3.1 Incomplete Data Collection and Integration Mechanisms** The CKD-specific tiered diagnosis and treatment system primarily relies on patient health records, prescription information, and laboratory data, depending on intelligent CDSS triggering mechanisms. However, inconsistent data formats and standards across institutions, relatively low informatization levels at community hospitals, and missing data have created challenges in data collection and aggregation standardization and completeness, with data cleansing processes yet to be perfected.

**3.2 Model Effectiveness Evaluation Requires Further Data Accumulation** The project is currently in pilot promotion phase, while long-term effectiveness evaluation of regional CKD prevention and control outcomes, health economics impacts, and social/policy implications requires substantial data accumulation. Future health economics evaluations will further analyze the model’s advantages and disadvantages in CKD prevention and treatment to enable continuous optimization.

### 4 Author Contributions and Conflict of Interest Statements

**ZHU Haiyan:** Responsible for manuscript drafting and writing; system development and research implementation.

**WANG Chaoxin:** Responsible for big data analysis and dominant disease selection; evidence-based medical protocol design and validation.

**SUN Wanju:** Responsible for research concept and design; final manuscript revision and overall accountability.

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