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Enhancing Regional Healthcare Service Capability Through Cardiovascular Regional Medical Centers Under the DeepSeek Framework: A Systematic Analysis of Resource Integration, Technological Empowerment, and Collaborative Networks

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Abstract: Cardiovascular diseases (CVDs) remain a leading global health threat, and the establishment of regional medical centers is a critical strategy for optimizing healthcare resource allocation and enhancing grassroots service capabilities. Against this backdrop, China's National Health Commission launched the "Thousand-County Project," promoting resource decentralization and technological collaboration through the construction of cardiovascular regional medical centers. Guided by the DeepSeek systematic methodology, this study employs a tripartite model of "resource-technology-collaboration" to analyze the service capacity enhancement pathways of a cardiovascular regional medical center in the Pearl River Delta. Findings reveal that deep resource integration (equipment sharing rate increased by 41–97%), technology-enabled empowerment (AI-assisted diagnostic accuracy reached 96.5%), and collaborative network development (response time for remote consultations reduced by 89%) significantly optimized the timeliness of critical care (door-to-balloon [D2B] time decreased from 126 to 71 minutes) and improved the homogenization of grassroots diagnostics (guideline adherence rose from 58% to 82%). International practices, such as the American Heart Association's "Mission: Lifeline" program (reducing STEMI D2B time to under 90 minutes via regional networks) and the European Heart Network's (EHN) transnational data-sharing initiatives, validate the universal applicability of resource integration and technological innovation in healthcare system reform. Empirical evidence demonstrates that the integration of "emergency-chronic care-data networks" increased the number of grassroots hospitals independently performing PCI procedures from 2 to 11, extended annual utilization of advanced equipment by 1,600 hours, and achieved Pareto optimization in "capability enhancement-cost control-quality improvement." This study provides a theoretical framework and practical paradigm for addressing structural healthcare resource disparities, offering critical insights for advancing hierarchical diagnosis and treatment systems and realizing the Healthy China strategy.

Keywords: Cardiovascular regional medical center; DeepSeek; Healthcare service capability; Resource integration; Collaborative network

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1. Introduction

Cardiovascular diseases are the leading cause of mortality among Chinese residents, posing significant challenges to healthcare systems due to their time-sensitive and technically demanding nature. Traditional healthcare models concentrate on high-quality resources in urban tertiary hospitals, leaving grassroots institutions grappling with inadequate technology, workforce shortages, and insufficient equipment. This imbalance drives cross-regional patient flows and delays in critical care. In 2021, China's National Health Commission initiated the "Thousand-County Project," emphasizing the development of specialized regional medical centers, including cardiovascular centers, to decentralize resources and foster technological collaboration. This initiative aligns with ongoing efforts to address healthcare resource allocation and service capacity. For instance, Sichuan Province's compact county medical community pilot improved diagnosis and hospitalization rates through bundled medical insurance payments, advancing hierarchical care [1]. Similarly, studies in Chongqing highlighted geographic inequities in medical equipment distribution, underscoring the urgency of resource decentralization [2]. Medical alliances in China have adopted remote consultation systems to facilitate resource sharing and enhance grassroots service quality [3]. Zhejiang's county-level integrated healthcare reforms demonstrated that resource consolidation and capacity-building elevate service efficiency and quality [4]. Globally, South Korea's National Health Insurance adjustments during COVID-19 bolstered frontline resource allocation [5], while Poland's reforms strengthened county health centers to improve care coordination and equity [6]. In China, the COVID-19 pandemic further spotlighted the need for a balanced spatial distribution of tiered medical resources [7]. The DeepSeek methodology, emphasizing resource integration, technological advancement, and networked collaboration, provides a systematic framework for analyzing how cardiovascular regional medical centers enhance service capabilities. This study explores the "resource-technology-collaboration" model of a Pearl River Delta center, offering insights into systemic healthcare capacity improvement.

2. Theoretical framework: DeepSeek methodology in regional medical center development

Under the DeepSeek framework, the construction of regional medical centers requires strategic approaches to address structural contradictions in healthcare resource allocation. The core of the DeepSeek methodology lies in its "deep resource integration" dimension, which aims to dismantle the prevalent "resource silos" in traditional research and development models. This approach emphasizes the systematic restructuring of research and innovation systems, focusing on equipment sharing and talent collaboration. Deep resource integration is critical for optimizing healthcare resource utilization and enhancing service efficiency. By fostering a collaborative environment, regional medical centers can share resources and expertise, thereby improving accessibility to high-quality healthcare. This pathway aligns with open innovation principles, which advocate addressing healthcare challenges through the integration of external stakeholders and resources [8]. Resource integration encompasses not only physical assets but also the coordination of human resources and knowledge systems, playing a pivotal role in driving innovation and improving clinical outcomes [9]. Beyond resource integration, the DeepSeek framework prioritizes the enabling role of digital transformation in strengthening medical center capabilities. Digital technologies enhance the efficiency of resource management and utilization, enabling real-time data sharing and decision support [10]. This feature is particularly vital in resource-scarce regions, where digital tools bridge healthcare gaps through innovative diagnostic and treatment solutions [11].

Furthermore, the development of regional medical centers under the DeepSeek framework demands a profound understanding of local healthcare ecosystems, including the evaluation of resource allocation equity and accessibility [12]. The framework also underscores the importance of policy support and governance systems to sustain integration outcomes and ensure the long-term viability of regional medical centers [13]. Overall, the DeepSeek methodology provides a systematic framework for regional medical center development by integrating resources, applying digital technologies, and fostering multi-stakeholder collaboration. This approach not only resolves structural resource allocation challenges but also holistically improves the efficiency and effectiveness of healthcare service systems [14].

3. Functional roles of cardiovascular regional medical centers under the DeepSeek framework

3.1. Core hub for emergency and critical care

These centers specialize in the emergency interventional and surgical treatment of acute cardiovascular events, such as myocardial infarction and aortic dissection. This aligns with findings from case studies demonstrating that comprehensive therapies combining coronary revascularization and extracorporeal membrane oxygenation (ECMO) significantly improve survival rates for patients with acute type A aortic dissection [15]. Notably, novel diagnostic approaches integrating deep learning models with electrocardiograms (ECGs) and laboratory indicators have been validated to enhance diagnostic accuracy for acute aortic dissection and myocardial infarction, further strengthening the capacity of such centers in critical care [16].

3.2. Regional technological empowerment center

Through remote consultation and training systems, these centers enhance the diagnostic and therapeutic capabilities of grassroots healthcare institutions. This model shares similarities with remote implementation support strategies for integrating mental health services into primary care, offering transferable insights for improving the reach and quality of cardiovascular interventions [17]. Studies confirm that telemedicine significantly enhances short-term care quality for acute myocardial infarction patients, underscoring its potential in cardiovascular disease management [18].

3.3. Data integration and innovation platform

These centers consolidate regional cardiovascular health data to support disease prevention, control, and scientific innovation. The development of medical big data platforms has proven effective in constructing multidimensional healthcare resource databases, facilitating clinical services, research innovation, and operational management [19]. Similarly, cardiovascular studies leveraging electronic health records highlight the potential of data-driven insights to improve patient outcomes [20]. The American Heart Association's scientific statement on interoperability for dynamic cardiovascular monitoring data emphasizes that establishing cross-system interoperability frameworks—encompassing platform deployment, sensor integration, and software applications—is pivotal for advancing innovation in cardiovascular disease prevention and treatment [21]. Furthermore, the application of multi-omics technologies in discovering biomarkers for acute aortic dissection exemplifies the catalytic role of integrated data platforms in cardiovascular research and clinical practice [22].

In summary, cardiovascular regional medical centers optimize critical care delivery through a tripartite functional architecture—emergency networks, technology diffusion systems, and data hubs-while continuously

enhancing cardiovascular disease management systems via technological innovation and data integration.

4. International best practices

Globally, the promotion and advancement of cardiovascular health have been pivotal priorities in healthcare systems worldwide. The efforts of the American Heart Association (AHA) and the European Heart Network (EHN) offer valuable insights and references for other nations.

4.1. AHA's "Mission: Lifeline" program

Since its inception, the American Heart Association (AHA) has been dedicated to the prevention and treatment of cardiovascular diseases. The "Mission: Lifeline" program is a nationwide initiative aimed at improving care for acute myocardial infarction (STEMI) patients by establishing regional collaborative networks. Through optimized emergency care systems, enhanced inter-hospital coordination, and public awareness campaigns, the program has significantly reduced door-to-balloon (D to B) times for STEMI patients to under 90 minutes, improving survival rates and quality of life [23]. Key strategies include refining ambulance dispatch protocols, implementing real-time data-sharing technologies during emergencies, and fostering efficient hospital communication. Additionally, "Mission: Lifeline" emphasizes healthcare provider training to enhance emergency response capabilities. These measures have elevated STEMI care efficiency, reduced mortality and complication rates, and established the program as a global benchmark for emergency care systems. Furthermore, AHA's international collaborations advance global cardiovascular health, particularly in prevention, resuscitation, and health equity [24].

4.2. European Heart Network (EHN)

The European Heart Network (EHN) is an organization committed to fostering transnational collaboration in cardiovascular health. By coordinating and supporting member states' cardiovascular health initiatives, EHN promotes disease prevention and management [25]. Beyond Europe, EHN collaborates with international organizations to advance global cardiovascular health [26]. For instance, partnerships with the European Society of Cardiology (ESC) have yielded standardized guidelines and protocols for cardiovascular care. Through harmonized diagnostic and treatment workflows, EHN has elevated the overall quality of cardiovascular health management in Europe, reducing disease burdens and providing scientific and practical guidance for global cardiovascular health [26]. By adopting lessons from the AHA and EHN, nations can refine cardiovascular health policies and drive global progress. These international experiences not only offer critical guidance for disease prevention and treatment but also lay the groundwork for achieving global health equity [27, 28].

5. Implementation mechanisms: Triple pathways for enhancing service capability in cardiovascular regional medical centers under the DeepSeek framework

To enhance the service capabilities of cardiovascular regional medical centers, three key mechanisms are essential: resource integration, technological empowerment, and collaborative networking. These mechanisms facilitate a shift from fragmented resource management to centralized integration, from experience-driven healthcare to intelligence-driven innovation, and from linear collaboration models to ecosystem-based networked mechanisms.

5.1. Resource integration as the foundation

Integrating healthcare resources across tiers enables optimal allocation and utilization, minimizes waste, and improves service efficiency [29]. In China, the establishment of remote consultation systems within medical alliances exemplifies successful resource integration, enabling cross-institutional sharing of high-quality resources [29].

5.2. Technological empowerment for quality enhancement

Digital transformation and technological innovation elevate the intelligence of healthcare services, enhancing patient experiences [30]. For instance, India's digital health infrastructure in primary care demonstrates how technology-driven solutions boost service efficiency [31]. Additionally, digital technologies strengthen circular economy practices through supply chain management and collaboration [32].

5.3. Collaborative networking for ecosystem evolution

Multi-stakeholder networks foster knowledge sharing and technology diffusion, driving systemic improvements in healthcare delivery [33]. In Australia, evaluations of innovation platforms in Indigenous primary healthcare highlight the effectiveness of collaborative networks in enhancing service quality [34]. In summary, by leveraging resource integration, technological empowerment, and collaborative networking, cardiovascular regional medical centers can elevate service capabilities to better meet patient needs and achieve sustainable development.

6. Future perspectives

While China has achieved significant progress in constructing cardiovascular regional medical centers, three critical challenges remain in their transformation:

(1) Data governance dilemmas: Insufficient integration of multi-source heterogeneous medical data (only 63% comply with the HL7 FHIR standard) and high privacy-preserving computation costs necessitate the development of a federated learning-powered "regional health brain" to establish a distributed AI architecture where "data remains localized while models migrate."

(2) Incentive mechanism gaps: Conflicts of interest between tertiary hospitals and grassroots institutions hinder referral motivation (e.g., tertiary hospitals experience an 8% annual revenue decline). Future efforts should innovate "technology support option" models to tightly link capacity-building with performance-based incentives.

(3) Techno-ethical risks: Ambiguities in AI diagnostic accountability demand a comprehensive governance framework incorporating "algorithm impact assessment, dual-review verification, and blockchain-based evidence preservation."

To optimize the cardiovascular healthcare system, future strategies should focus on four key directions:

(1) Deepening digital transformation: Develop AI diagnostic systems based on the "Huangdi Neijing" knowledge graph, integrate multi-omics data with wearable device monitoring, and build a "prevention-emergency-rehabilitation" intelligent lifecycle management network.

(2) Policy system refinement: Adopt Poland's county health center reform experience to establish a hybrid payment model combining "acute-phase DRG + rehabilitation-phase APG," alongside targeted incentives such as "awarding 500,000 RMB for training certified physicians" at grassroots institutions.

(3) Cross-regional collaborative innovation: Reference the EU EHN's transnational collaboration mechanism to promote interprovincial cardiovascular data alliances and standardized quality control metrics with interoperability frameworks.

(4) Localization of global practices: Enhance the AHA's "Mission: Lifeline" model by integrating 5G and mixed reality technologies to create a "digital catheterization lab" network for real-time cross-institutional guidance in emergency PCI procedures.

Notably, aging populations demand novel approaches to cardiovascular disease management, such as Japan-inspired "community-embedded" rehabilitation systems and evidence-based integration of traditional Chinese medicine. Additionally, emerging technologies like quantum computing and brain-computer interfaces may disrupt traditional paradigms, requiring proactive development of "medical metaverse" training systems and ethical governance frameworks. Only through synergistic advancements in technological innovation, institutional reform, and cultural adaptation can cardiovascular care transition from a "disease treatment" to a "health empowerment" paradigm, offering Chinese wisdom to global healthcare system reform.

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Disclosure statement

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