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Optimization Review of Online-Offline Cooperative Medical Alliances under China's Tiered Diagnosis and Treatment Policy

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Abstract

Tiered diagnosis and treatment (TDT) is a key lever for balancing medical resources, improving the efficiency of medical alliances, and mitigating China's "difficult and expensive access to care" problem. With rapid advances in digital technologies, the research focus on TDT has broadened to include remote medical services and online-offline collaboration. This review synthesizes domestic and international literature on two fronts: (1) how remote medical services facilitate TDT and (2) how digital transformation drives cooperative medical alliances. Although many studies investigate internet-enabled TDT, few address system-level collaboration among multi-tier hospitals to ensure the downstream flow of high-quality resources, and most digital applications remain limited to basic information sharing. There is a lack of research on digital system optimization and integrated online-offline strategies. After assessing the gaps, this paper proposes future research directions to guide the optimization of digitally supported cooperative alliances.

Keywords

Tiered Diagnosis and Treatment; Medical Alliance; Digital Transformation; Online-Offline Collaboration; Literature Review.

1. Introduction

"Difficult and expensive access to medical services" is still a critical public concern in China. TDT receives significant policy attention because it can optimize resource allocation and improve the operation of medical alliances. Recent governance documents emphasize strengthening county-township-village cooperation, expanding primary care access for common and chronic conditions, and promoting high-quality resources to flow downward. Meanwhile, the TDT regime still faces low information efficiency, lengthy referral procedures, and limited patient trust in grassroots services. Consequently, theoretical and practical innovations in TDT remain a major research focus.

The digital era presents both opportunities and challenges. Diverse patient demands, complicated care pathways, and referral processes with priority or blocking constraints render traditional offline alliances insufficient; the limited growth of medical resources and shortage of highly skilled staff further drive the integration of digital solutions. The priority question becomes how to use "online + offline" models to dynamically allocate resources and enhance collaboration efficiency. This paper concentrates on the optimization of online-offline cooperative medical alliances under TDT. It analyzes existing studies, identifies gaps, and recommends feasible directions that integrate TDT with digital health, queuing optimization, and collaborative governance. Practically, it offers insights for policymakers and alliance managers in directing high-quality resources to lower levels, managing referrals, and improving service efficiency.

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2. Overview of Tiered Diagnosis and Treatment Research

2.1. International Practices and Theoretical Research

Countries such as the United Kingdom, the United States, and Australia have mature TDT frameworks. The UK relies on general practitioners as gatekeepers; the NHS pairs this with electronic referral systems to maintain continuity. The US uses managed care structures (HMO, PPO) to keep patients in-network, while Australia enforces strict two-way referral standards to ensure seamless transitions across tiers.

Theoretical research spans queuing networks, optimization, and system dynamics. Luo and Kong used queuing models to align arrival rates and service capacity[1]; Xiao et al. modeled light and severe patient flows in alliances and proposed short- and long-term optimization policies[2]; Blair and Lawrence built finite-capacity multi-server queue models with Markov chains for burn-care allocation[3]. Yuan studied single- and double-referral mechanisms in both steady-state and blocking environments[4]; Kowalska introduced patient demand characteristics at different stages to forecast arrivals, estimate resource costs, and plan referral and capacity decisions[5]. Wang et al. applied robust optimization to allocate core physician time in cloud-based systems with uncertain referrals[6]. These efforts enrich TDT resource modeling and create a foundation for digital era experimentation.

2.2. Domestic Research Progress

Chinese scholars focus on policy evolution and local implementation. Wang Hufeng outlined TDT development stages and key policies[7]; Zhou conducted a systemic review highlighting regional disparities, data silos, and capacity constraints[8]; Shen emphasized the mismatch between crowded tertiary hospitals and underutilized grassroots facilities[9]; Lv proposed integrated chronic-care networks[10]. Despite national promotion of medical alliances, grassroots implementation remains uneven, prompting ongoing policy adjustments in provinces like Beijing, Shanghai, and Zhejiang. Their programs on referral pathways, insurance payment reform, and information infrastructure offer practical lessons for improving alliance operations.

3. Remote Medical Services Supporting Multi-Tier TDT

Remote medical services address information delays and referral bottlenecks. Studies introduce self-service portals, online consultation platforms, and centralized treatment centers to stratify patients and increase resource use efficiency. Other work designs digital two-way referral platforms or bi-objective models to boost collaboration, standardizing data sharing across imaging, ECG, and laboratory services[11].

Information sharing is pivotal. Researchers propose big-data frameworks, unified interface standards, and high-performance architectures. National data centers and remote medical hubs are gradually opening standardized interfaces for primary institutions, enabling EMR sharing, remote prescriptions, and teleconsultations. Yet, most studies focus on technical platforms rather than system-level cooperation; multi-tier coordination, interface alignment, and operational governance still lack robust models[12-14]. Practical pilots pair internet hospitals with primary centers, adopt AI-assisted diagnostics to support grassroots clinicians, and build "Internet + family doctor" applications for chronic disease management. These cases show tangible benefits but leave gaps in cross-tier processes, incentive alignment, and integrated decision making.

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4. Digital Transformation for Online-Offline Cooperative Medical Alliances

China's expanding electronic health records, EMRs, and regional platforms have generated large-scale data assets. Chongqing's regional information platform captures continuous records and supports analytics for TDT[15]; Shanghai's municipal center processes billions of medical entries for appointment scheduling, prescription extension, and logistics, connecting residents with providers; Beijing's EMR portal integrates hospital records with mobile appointment services; Shanghai's Xuhui District uses remote imaging centers to deliver tertiary services to community patients; Luoyang and Ningbo combine double-referral systems with telemedicine and chronic disease risk prediction[16, 17]. These cases demonstrate that digital tools can streamline coordination and broaden access.

However, many digital projects still target information sharing rather than comprehensive system optimization. Key challenges include integrating remote consultations with offline outpatient and inpatient care, managing patient flow at different severity levels, and linking heterogeneous data to decision-support systems. Proposed directions include building end-to-end models covering online scheduling, offline diagnosis, remote testing, and rehabilitation; adopting queuing networks, stochastic optimization, and reinforcement learning to simulate multi-tier flows; and integrating insurance data with performance metrics for joint resource allocation [1][2][13].

Digital alliances also need robust data standards, governance mechanisms, and privacy protections. Unified coding, interface alignment, data quality control, and legal frameworks are essential foundations. Organizational innovation—such as regional medical operations centers, shared performance metrics, and cross-institutional clinical pathways—can sustain collaboration. Some studies advocate a "platform + center + network" architecture to aggregate data, disseminate expertise, and deliver community services within a single ecosystem.

5. Research Gaps and Future Directions

5.1. Achievements

The literature has advanced institutional design, optimization models, and digital applications. Robust optimization, multi-objective modeling, and simulation contribute to handling uncertainty. Implementation cases demonstrate progress in telemedicine, cloud hospitals, and medical alliances. Internationally, scholars propose patient-demand segmentation to refine service modes, offering valuable references for China's TDT initiatives.

5.2. Key Limitations

1. Lack of collaborative online-offline mechanisms: Remote and physical services remain disconnected.

2. Insufficient modeling detail: Few models incorporate priority queues, blocking, behavior differences, or multi-stage patient journeys.

3. Weak multi-tier coordination: Standardized data interfaces and governance are still missing.

4. Digital applications stop at information sharing: Decision-support, intelligent scheduling, and system-level optimization are underdeveloped.

5. Limited dynamic and scenario analysis: Seldom do studies evaluate how shocks (e.g., outbreaks, policy shifts) affect resource allocation.

6. Inadequate patient segmentation: Chronic, elderly, and emergency pathways lack tailored strategies.

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7. No comprehensive evaluation framework: There is a need for indicators that reflect quality, patient experience, and economic efficiency.

5.3. Future Research Directions

1. Build integrated online-offline optimization models capturing arrival rates, service capacity, resource utilization, and incentive mechanisms.

2. Develop queuing networks with priority and blocking constraints, validated via simulation.

3. Design multi-tier governance structures with standardized interfaces, referral hubs, and secure data protocols.

4. Upgrade digital platforms toward decision-support, intelligent scheduling, and system optimization using AI, knowledge graphs, and federated learning.

5. Run short-term and long-term scenario analyses to evaluate policy, demographic, or epidemic impacts.

6. Segment patient groups and model multi-stage pathways for chronic disease, elderly care, and acute treatment.

7. Create multi-dimensional evaluation frameworks to guide policy iteration and resource investment.

6. Conclusion

TDT research now encompasses institutional development, resource optimization, and digital implementation. Yet realizing a fully integrated digital alliance that seamlessly coordinates online and offline services remains an open challenge. Drawing on international and domestic literature, this review highlights seven research priorities: comprehensive optimization models, advanced queue networks, multi-tier governance, decision-support upgrades, dynamic scenario analysis, patient segmentation, and holistic performance evaluation. Addressing these areas can accelerate the balanced allocation of medical resources, reinforce primary care capabilities, and ultimately deliver better healthcare outcomes in the digital era.;

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