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Review

Exploring key issues in the development of smart hospitals

Shengwen Gao*

School of Engineering and Technology, Nanchang Vocational University, Nanchang 330013, China.

Abstract
With the rapid evolution of information technology and the continuous advancement of healthcare reform, the construction of smart hospitals has become a critical initiative to enhance the quality and efficiency of medical services. This paper begins by providing a comprehensive understanding of smart hospital construction, discussing its significance, planning objectives, and guiding principles. It also examines the current challenges facing the development of smart hospitals in China and proposes a series of specific measures to address these issues. The aim is to offer insights for advancing the construction of smart hospitals and support the transformation of traditional hospitals into smart hospitals.

Keywords: Hospital informatization; smart hospital; construction pathway

1 Introduction

The rapid development of i--nformation technology has accelerated the transition of various industries in China toward deeper digitalization. As a cornerstone of the healthcare system, hospitals are steadily evolving from informatization to digitalization and smart transformation, with electronic medical records serving as the foundation for establishing comprehensive hospital information systems [1].

Smart hospitals are an inevitable product of adapting to changing patient needs and technological innovation. In August 2014, China's National Development and Reform Commission, along with eight other government departments, issued the *Guidance on Promoting Healthy Development of Smart Cities*, marking the first proposal for smart hospital construction. By June 2021, the State Council emphasized the importance of deeply integrating new-generation information technologies with healthcare services in its *Opinions on Promoting High-Quality Development of Public Hospitals* (State Council Document [2021] No. 18). This document called for accelerating the standardization and development of smart hospitals.

Smart hospitals represent a comprehensive embodiment of intelligent development in hospitals, rather than a simple aggregation of technologies or isolated functionalities. Merely introducing smart tools into hospitals does not equate to the establishment of a smart hospital. This endeavor requires long-term investment and entails extended payback periods, making resource allocation a significant challenge for researchers and hospital administrators with limited funding [2].

Smart hospitals are characterized by three core elements: informatization, internetization, and intelligentization.

• Informatization involves establishing integrated data systems encompassing patients, medical staff, and hospital operations, as well as data governance and business application platforms.

• Internetization integrates online and offline hospital services through mobile, cloud-based, and virtual systems to deliver seamless, end-to-end care for patients before, during, and after treatment.

• Intelligentization optimizes medical services and hospital management using big data, cloud computing,

***Correspondence**
Shengwen Gao
School of Engineering and Technology, Nanchang Vocational University,Nanchang 330013,China.
E-mail: 2385270474@qq.com

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blockchain, IoT, automation, robotics, AI-assisted technologies, and operational management systems.

2 The Significance of Smart Hospital Development

2.1 Enhancing Support for Healthcare Providers

One primary goal of smart hospital development is to improve healthcare providers' work experience and operational efficiency. By leveraging electronic medical record systems as a central platform, smart hospitals seamlessly connect departments such as diagnostics, imaging, and finance, facilitating smoother service delivery.

Collaborations between hospitals and enterprises have advanced the application of AI in healthcare. For example, AI-powered tools for diagnosing pulmonary nodules have demonstrated diagnostic accuracy comparable to human radiologists while achieving superior sensitivity in nodule detection [3]. These capabilities significantly enhance diagnostic precision, offering reliable clinical insights and exemplifying the value of smart hospital technologies in improving care quality.

2.2 Improving Patient Experience and Efficiency

Smart hospital services are patient-centered, reflected in three key aspects: 1. Convenient Access: Integrating internet technologies with medical services, such as self-service payment kiosks, lab result retrieval terminals, and mobile health apps, allows patients to schedule appointments and consult with doctors anytime, reducing spatial and temporal barriers; 2. Smart Follow-Up and Post-Treatment Support: Online platforms like telemedicine and cloud-based consultations enable video consultations, remote monitoring, intelligent health management, and medication guidance; 3. Efficient Navigation: Systems like smart parking and navigation, utilizing GIS and hospital maps, provide patients with precise directions, minimizing unnecessary travel time. These innovations streamline interdepartmental collaboration, ensure smooth medical workflows, and significantly reduce patient waiting times, enhancing overall satisfaction with hospital services.

2.3 Optimizing Hospital Management

Smart hospital management encompasses two main domains: 1. Operational Management: Advanced systems enable precision in areas like research management and surgical scheduling, making administrative processes more efficient and comprehensive; 2. Logistics Management: Cloud technologies and IoT integration support efficient warning systems and real-time visualization, boosting logistics and resource allocation capabilities [4]. Incorporating these measures enhances hospital informatization and provides a robust foundation for sustained smart hospital development.

3 Objectives for Smart Hospital Development

The core objective of smart hospital construction is to deploy high-quality, user-friendly intelligent systems to support patients throughout their healthcare journey, from pre-diagnosis appointments to post-treatment rehabilitation. This comprehensive approach seeks to meet the needs of patients, healthcare professionals, and administrators, creating a service framework that is efficient, integrated, and patient-focused.

While informatization has been applied in clinical, disease management, and rehabilitation services, it has not fully addressed evolving health demands. Future trends will focus on integrating health management, prevention, guidance, and intervention to enhance patient well-being comprehensively. Intelligent functionalities such as real-time alerts, verification, and collaboration will further improve service quality and safety [5].

To strengthen regulatory oversight, introducing real-time monitoring and early warning systems is recommended. These systems will enhance problem identification and resolution, supported by robust analytical frameworks, benchmark metrics, and data infrastructures. Such advancements will ensure safe, efficient, and high-quality healthcare services.

4 Fundamental Principles for Smart Hospital Development

4.1 Principle of Openness and Collaboration

The core of building a smart hospital lies in the deep integration of information technology, internet technologies, and artificial intelligence. Hospitals should transcend traditional models and adhere to the principle of openness and collaboration to drive transformation [6]. This principle manifests in two dimensions:

• Breaking away from conventional diagnostic ap-

proaches and service models by avoiding rigid thinking and integrating advanced methods, technologies, and concepts tailored to the functional needs of smart hospitals.

• Establishing an open information-sharing ecosystem that enhances the openness of information linkage systems, facilitating data exchange between hospitals and external entities to better fulfill their social responsibilities.

4.2 Principle of Standardization and Unification

Standardized information and unified data are prerequisites for building smart hospitals and ensuring seamless interconnectivity. This is critical for enhancing system efficiency. Hospitals must strengthen the standardization of data management and strictly comply with local, industry, and national standards. Additionally, these standards must be implemented in the construction of data platforms, data centers, information systems, and databases.

4.3 Patient-Centered Principle

As public awareness of healthcare grows, so does the demand for quality medical services. Hospitals must align closely with patient needs, optimizing and innovating to ensure services are patient-oriented. This principle requires the development of medical modules, business processes, and service systems that provide human-centered, efficient, and convenient care, enhancing patient satisfaction [7].

4.4 Principle of Information Security

In the era of big data, ensuring information security is critical. Hospitals handle sensitive patient data, and any breach or loss of such information can harm patients and threaten societal stability. To ensure data security, hospitals must adopt robust measures like firewalls, encryption, and biometric technologies to protect against hacking, viruses, and malicious software.

4.5 Prevention-Focused and Control-Enhanced Principle

As the primary site for disease prevention and integration of medical and preventive services, hospitals must leverage smart technologies to strengthen infectious disease monitoring, evaluate chronic diseases, and enhance diagnostic guidelines. Quality management, infection control, and medical dispute prevention are also critical components of this principle.

4.6 Principle of Progressiveness and Leadership

Smart hospitals must evolve with technological advancements and societal changes [8]. Current trends include extensive use of electronic medical records, regional medical information integration, personalized care models, precise medicine, and the online and mobile implementation of smart medical services.

5 Key Challenges in the Development of Smart Hospitals in China

5.1 Lack of Top-Level Design

With the popularization of the smart healthcare concept and intelligent technologies, many hospitals are beginning to undergo digital transformation. However, in practice, many hospitals merely pile together various information products without considering the relationships and compatibility between systems. This results in frequent ad-hoc adjustments during the construction process, lacking a top-level design that considers the overall hospital architecture.

5.2 Poor System Integration

Currently, the construction of smart hospitals focuses primarily on the application of individual systems, developing software or systems tailored to specific needs. However, these systems lack effective mechanisms for data integration, leading to "data silos" that severely hinder interconnectivity and data sharing within hospitals. This not only obstructs the establishment of a comprehensive database system and cross-regional data sharing but also leads to wasted data resources.

5.3 Insufficient Coordination in Management

The development and management of smart hospitals require collaboration across multiple departments, including information technology, infrastructure, administration, and clinical operations [9]. However, many hospitals currently face challenges such as a shortage of skilled professionals, unclear delineation of departmental responsibilities, incomplete collaboration mechanisms, and barriers to information sharing. These issues significantly impede the overall management level of smart hospital construction.

5.4 Gaps in Construction Guidance Systems

Since 2018, the National Health Commission has issued several guiding documents, such as the *Standards and Norms for National Hospital Informatization Construction (Trial), the Hospital Smart Service Grading Assessment Standards System (Trial)*, and the *Hospital Smart Management Grading Assessment Standards System (Trial)*. While these provide reference frameworks for assessing the level of smart hospital development, they focus more on post-construction evaluation rather than offering specific guidance for the construction process itself. This necessitates the development of a more comprehensive and systematic set of standards to fill this gap [10].

5.5 Challenges in Multi-Campus Data Sharing

Many hospitals in China still face significant limitations in achieving data sharing during modernization efforts. The overall resource-sharing system remains underdeveloped, and awareness of the value of data sharing among stakeholders needs to be enhanced. This hinders progress in integrated construction efforts. Moreover, managing large volumes of dispersed data is cumbersome and inefficient, highlighting the need for improved data standardization. Additionally, the slower pace of multi-campus data integration system development complicates remote collaboration. Fragmented data collection delays reporting, negatively affecting hospital management precision, scientific decision-making, and the provision of remote medical services. These challenges increase the workload and pressure on medical staff.

6 Specific Measures for Smart Hospital Development

6.1 Refining Top-Level Design

Building smart hospitals requires a systematic approach rooted in comprehensive planning. This planning must encompass all dimensions of smart hospital construction, from infrastructure layout to information system development, ensuring careful consideration at every stage. A well-structured plan ensures that facility upgrades and equipment introductions adhere to established guidelines, bridging theory with practice [11]. Equipment planning should align with the hospital's actual needs and financial conditions to create cost-effective procurement and deployment strategies.

Accurate clinical outcomes and quality are critical in advancing smart hospital development. Adopting state-of-the-art technologies and equipment significantly improves diagnostic precision and treatment efficiency. To optimize patient experiences, hospitals should innovate in business processes and service models, promoting refined hospital management. Technological innovation is vital for the continuous progress of smart hospitals, as it enhances medical services, supports sustainable development, and strengthens healthcare quality [12].

6.2 Upgrading Intelligent Applications of Electronic Medical Records

Implementing strategies for paperless, intelligent, and closed-loop management of medical records can significantly improve their utilization efficiency. EMRs are essential components of healthcare systems, and transitioning to paperless management addresses existing system challenges. Structured EMRs should be treated as foundational to smart hospital construction, with systematic management and graded assessments to enable in-depth clinical data analysis and efficient utilization.

Systematic evaluations of key areas such as rational medication use, clinical surgery, and postoperative care are necessary to build knowledge bases that support clinical decision-making. Integrating these knowledge bases with EMR systems facilitates more accurate diagnoses and enhances care quality. Intelligent features such as reminders and decision support streamline processes like prescriptions, transfusions, and medication administration, ensuring closed-loop management of medical procedures.

6.3 Building a Patient-Centric Service System

Hospitals should adhere to a patient-first principle, establishing an extensive, multidimensional patient service ecosystem. Patient-centric service concepts are widely recognized, and smart hospital development should prioritize creating systems that rapidly respond to patient needs while offering fundamental medical guarantees and intelligent service solutions. Enhancing the humanization and intelligence of patient services is a core mission.

This service system should encompass the entire patient journey, from pre-appointment scheduling and in-treatment care to post-treatment recovery. It must integrate offline services, such as outpatient and inpatient care, with online services, including telemedicine and

virtual consultations. The system should also bridge in-hospital and out-of-hospital resources, ensuring timely and precise care across diverse channels [13]. Hospitals must continuously improve service quality by focusing on key areas like home care, convenience enhancement, quality control, and emergency collaboration, with an emphasis on patient satisfaction and service accessibility.

6.4 Developing Big Data Platforms for Research Enablement

Constructing research and analysis platforms for medical imaging based on clinical information and omics data is a strategic move. As hospitals progress in digitization, they amass diverse patient case data, forming a solid foundation for clinical diagnosis and research. However, fragmented business systems and disorganized data require a unified three-tier clinical research big data platform, comprising business systems, a clinical data center, and a data application layer.

The clinical data center houses unaltered raw data, which is processed using intelligent techniques to enhance usability. This data should align with hospital needs and scientific rigor to create a professional pathology database. This platform supports data retrieval, case classification, patient tracking, and analysis, significantly improving research efficiency. Ensuring data quality, security, and patient privacy remains a critical challenge in medical big data applications.

6.5 Advancing Resource Planning and Integration

Efficient resource planning is integral to smart hospital development. This involves merging enterprise resource planning principles with existing hospital information systems. Using reverse design thinking, hospitals can build integrated, intelligent, unified, and interconnected resource management platforms tailored to user needs and operational conditions [14].

Information technology enables close integration of hospital facilities, such as inpatient and outpatient buildings, while electronic tags facilitate precise tracking and distribution of medical supplies. These advancements improve management efficiency and resource flow. Automated performance evaluation systems that enable rapid data processing, in-depth analysis, and immediate feedback enhance management effectiveness and staff satisfaction. Such frameworks ensure optimal resource allocation and elevate overall hospital management.

6.6 Creating Multi-Campus Data Sharing Platforms

A unified data-sharing platform for multi-campus hospitals eliminates information silos, enabling seamless integration and accessibility of patient information across campuses. Each campus retains autonomy over data management, tailoring management permissions to its needs. This approach ensures convenient data sharing while maintaining security and privacy.

Inter-campus data connectivity supports record sharing, bolstering research and clinical collaboration. It facilitates cross-campus consultations and remote video diagnoses, allowing specialists to access patient records from different campuses for swift medical assessments. Patients also benefit from accessing records from the nearest campus, simplifying processes and enhancing service efficiency.

6.7 Establishing Collaborative Medical Systems

Advancements in 5G and blockchain technologies are accelerating the development of cloud-based collaborative networks. Smart hospitals aim to connect healthcare institutions through an integrated information network that ensures efficient circulation of patient data and services.

5G technology, with its high bandwidth, low latency, and extensive connectivity, shows immense potential in remote medical consultations, training, and monitoring. Blockchain technology addresses traditional challenges in medical information sharing by ensuring data security, immutability, and traceability, while safeguarding patient privacy. Together, these technologies offer promising applications for smart hospitals. Looking ahead, smart hospital systems will transcend individual facilities, leveraging integrated healthcare networks to deliver patient-centered, cloud-supported collaborative services [15].

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