ISSN:3068-9376

*Frontiers in Preventive Medicine* (2025), 36-43

doi: 10.64904/fpm25004

**Review Articles**

# Reform Pathways for Healthcare Institution Management in the Context of National Infectious Disease Surveillance and Pre-Warning Software Systems

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**Abstract**

**Objective** To study the driving role of the deployment and application of the national infectious disease monitoring and early warning front-end software in enhancing the management mode and efficiency of medical institutions, and to provide more theoretical support and practical reference for the establishment of digital medical management system in the new era. **Methods** To analyze the technical principles and core functions of the National Infectious Disease Surveillance and Early Warning Front-end Software, and to reveal the driving role of the National Infectious Disease Surveillance and Early Warning Front-end Software related technologies in the medical management mode of organizational structure, workflow, information management, personnel responsibilities, and resource allocation through the analysis of systematic literature and theoretical retrospective causes. **Results** The deployment and application of national infectious disease surveillance and early warning precursor software will drive the transformation of healthcare organizations' management model to data intelligence, but the change may face challenges such as technological integration, organizational inertia, and ethical risks. **Conclusion** The hospital management model driven by the NIDSS is transforming from "experience-driven" to "data-intelligence-driven", and the change of its management model is essentially a self-adaptive revolution of healthcare organizations into the era of digital healthcare, which requires the use of intelligent algorithmic modeling technology, organizational inertia, and ethical risks. It is necessary to make breakthroughs in intelligent algorithmic modeling technology, digital literacy competence certification and data regulatory innovation system to build a modern medical management system that combines "level and urgency".

**Keywords:** national infectious disease surveillance and early warning front-end software; healthcare management model; data driven

## 1. Introduction

Due to the fact that the transmission of newly emerged or re-emerged viruses is not constrained by geographical boundaries [1], coupled with the

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frequent emergence of new and re-emerging infectious diseases and the increasing intensity of cross-border mobility, the global landscape of infectious disease prevention and control has become increasingly complex and diverse [2]. In recent years, with advancements in infectious disease surveillance technologies and management practices, significant progress has been achieved in disease prediction models and case tracking systems leveraging big data and artificial intelligence [3]. Desjardins [4] were among the first to apply prospective spatio-temporal scan statistics for clustered monitoring and early warning of the COVID-19 pandemic in the United States, enabling timely identification of locations and time periods requiring enhanced targeted interventions, testing site deployment, and necessary isolation measures. In China, emphasis has been placed on improving surveillance efficiency through information technology. For example, Yang Weizhong et al. from Peking Union Medical College [5] proposed the establishment of a multi-source trigger mechanism and a multi-channel monitoring and early warning system for intelligent detection of infectious diseases. By systematically designing strategic frameworks for infectious disease surveillance and early warning, efforts are underway to build a unified national intelligent early warning platform and a blockchain-based management system for integrating multi-channel data, thereby enhancing real-time analysis, centralized evaluation, and early response capabilities for infectious diseases.

Against this backdrop, the National Disease Control and Prevention Administration has launched a pre-deployed software system for intelligent monitoring and early warning of infectious diseases, implemented through integrated deployment within medical institutions in accordance with national unified standards, aiming to improve the timeliness and accuracy of infectious disease surveillance [6]. As a public health information solution integrating big data analytics and intelligent modeling algorithms, the National Intelligent Monitoring and Early Warning System for Infectious Diseases not only streamlines the surveillance and early warning workflow but also facilitates comprehensive transformation and upgrading of institutional management practices in healthcare settings. This study aims to examine the application and transformative impact of this national intelligent monitoring and early warning system, and to explore its potential in supporting medical institutions to achieve precise prevention and control strategies and enhance their overall management effectiveness.

## 2. Overview of the National Intelligent Infectious Disease Monitoring and Early Warning Pre-Deployment Software

### 2.1 Technical Principles

The National Intelligent Infectious Disease Monitoring and Early Warning Pre-Deployment Software employs a three-tier network architecture comprising an internal network, government extranet/VPN (Virtual Private Network), and a data integration service platform. Centered on the technical framework of "dynamic round-robin – post-structural processing – intelligent tagging," the system establishes a real-time data collection and transmission mechanism. It primarily creates real-time data channels with outpatient and inpatient Electronic Medical Record (EMR) systems in medical institutions via API interfaces, transmitting clinical data—including medical records, laboratory test reports, and treatment medications—to the software's server component in real time (T+0) or at predefined intervals (e.g., every 2 hours, T+1), in compliance with the Computerized Infectious Disease Reporting (CIDR) standard. The software utilizes Natural Language Processing (NLP) and other advanced technologies to perform post-structural processing on multi-modal, heterogeneous monitoring data, enabling dynamic updates. Through continuous intelligent monitoring via dynamic round-robin scanning, the system identifies cases requiring reporting. Structured case data are then transmitted via API interfaces to regional platforms and the national direct reporting system, thereby enabling end-to-end monitoring and management.

### 2.2 Core Functions

Centered on fulfilling platform service requirements, the National Intelligent Infectious Disease Monitoring and Early Warning Pre-Deployment Software integrates five key functional modules: data interoperability, intelligent surveillance, closed-loop management, visualized collaboration, and system security. Supporting seamless coordination across server, PC, and mobile endpoints, the system functions as an intelligent hub for infectious disease monitoring, facilitating the principles of "early detection, early warning, and early response."

2.2.1 Positive Result Alert

The software assigns a "to be confirmed" tag to flagged cases. By continuously monitoring the Laboratory Information System (LIS), it detects specimens with positive results and automatically triggers a "to be confirmed" alert, initiating timely case tracking and follow-up procedures.

2.2.2 Automated Reporting

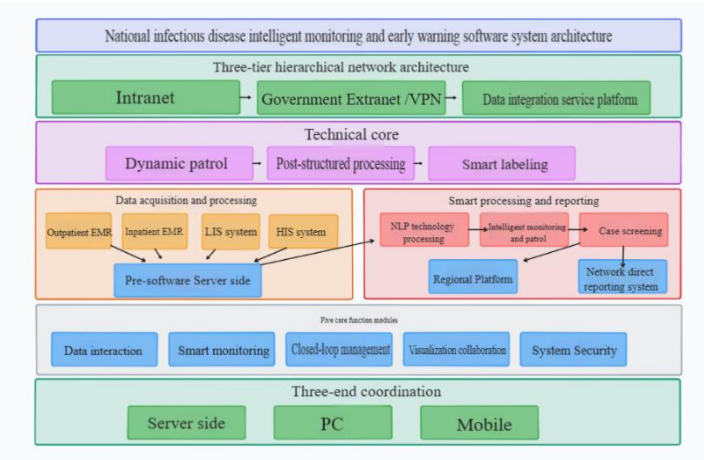
The system automatically extracts relevant clinical data from the Hospital Information System (HIS) and Electronic Medical Record (EMR) systems, generates standardized infectious disease report cards, and performs automated preliminary validation to ensure data completeness and accuracy prior to submission.

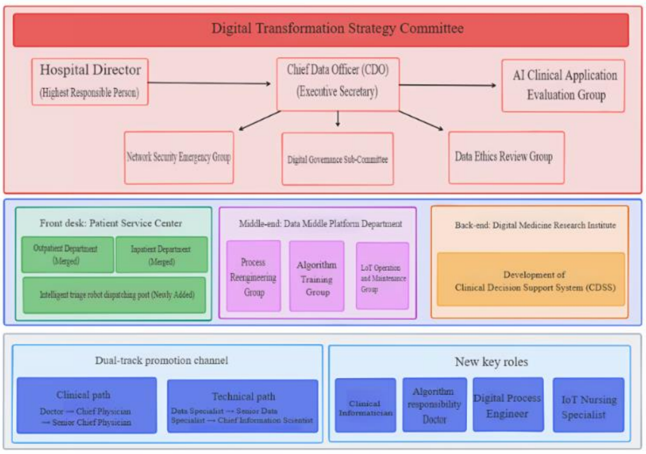
2.2.3 Abnormality Detection Alert

Leveraging artificial intelligence-driven algorithmic models, the software analyzes integrated health data streams to detect anomalous trends indicative of potential outbreaks. Upon identifying statistically significant deviations, it activates the early warning mechanism and notifies public health monitoring units and disease control agencies, facilitating coordinated investigation and timely intervention.

## 2.3 Application Status

The national intelligent monitoring and early warning front-end software for infectious diseases is led by the National Disease Control and Prevention Administration and implemented and operated by the Chinese Center for Disease Control and Prevention. It adopts a division of labor and collaboration approach, with the state responsible for software development and upgrade improvement, and provinces coordinating regional organization and deployment for implementation. Since the National Disease Control and Prevention Administration issued relevant documents such as the "Notice on the Deployment of the National Intelligent Monitoring and Early Warning Software for Infectious Diseases" in July 2024, the integration and deployment rate in secondary and above medical institutions across the country has reached 71% [7]. The promotion of the National intelligent monitoring and early warning software for infectious diseases will further extend to primary-level medical and health institutions in the future. The ultimate goal is to achieve full coverage of the deployment and application of national front-end software in medical institutions at all levels and of all types.



## 3. The transformation path of medical institution management model based on front-end software

At present, big data analysis technology has become a key pillar in the healthcare field. Based on the in-depth mining of massive patient data, medical institutions can achieve real-time data monitoring and dynamic process management [8]. By using predictive analysis models, the fluctuation trends of admission rates in different periods can be predicted in advance, medical resources can be intelligently allocated and managed, and the operational efficiency of medical institutions can be improved [9]. Therefore, the multi-source data integration and analysis early warning technology of the national intelligent monitoring and early warning software for infectious diseases also provides underlying support for the transformation of the management model of medical institutions. For instance, its data collection and analysis function can promote the automation transformation of the outpatient triage process in medical institutions and the automatic classification and handling of patient complaints through natural language processing (NLP) technology [10]. The following will systematically expound on the reshaping path of the management model of medical institutions based on the technical advantages of the national intelligent monitoring and early warning software for infectious diseases.

### 3.1 Path for Organizational Structure Reshaping

Research shows that a solid organizational management structure is a key factor in realizing emerging technologies such as health big data analysis [11]. Therefore, a clear organizational structure with well-defined responsibilities is a key constraint for the implementation of these technologies. If a digital transformation strategy committee is established, directly led by the president and with the chief data officer as the executive secretary, the decision-making power of the medical, information and research departments will be integrated. At the same time, a digital governance sub-committee will be set up, with a data ethics review group, an AI clinical application evaluation group and a cybersecurity emergency response group under it. At the business level, a front-middle-back architecture was established. The front end merged the outpatient department and inpatient department into a patient service center and added an intelligent guidance robot dispatching position. The middle end upgraded the information Department to a data middle platform department, which included a process reengineering group, an algorithm training group, and an Internet of Things operation and maintenance group. The back end reorganized the Science and Education Department into a Digital Medicine research institute, specializing in the development of clinical decision support systems. At the same time, during the reform of the job system, a dual-track promotion channel has been set up, namely the clinical path (physician → chief physician) and the technical path (data specialist → chief information scientist). Four key roles have been newly added: clinical information scientist (a compound talent of clinical and data), algorithm responsibility physician (clinical supervisor of AI models), digital process engineer (expert in medical business process transformation), and Internet of Things nursing specialist (person in charge of intelligent equipment operation and maintenance). As studied by Terhi-Maija Isakov [12] et al., it is believed that the digital transformation of organizational management in hospital home care can enhance the overall efficiency of the healthcare system and promote equity and universal access to high-quality healthcare for the public.

### 3.2 Workflow Reengineering Path

The core function of medical and health services is to meet the health needs of the people. However, with the transformation and upgrading of health demands and the increase of health risk factors, the focus of medical and health services has shifted from "treatment-centered" to "prevention-centered" health intervention methods [13]. Therefore, the optimization of medical service processes mainly focuses on two aspects: the outpatient and inpatient work processes. The optimization of the outpatient workflow mainly lies in the data analysis capabilities and dynamic risk perception capabilities of the front-end software to conduct key tests on high-risk patients, thereby achieving the forward movement of examinations and tests. At the same time, when prescribing, the automatic recognition and analysis capabilities of the front-end software can be utilized, and a medication risk interception mechanism can be added to achieve the function of intercepting drug interaction risks. The optimization of the inpatient management workflow mainly lies in generating a visual progress prediction board for the patient's disease course based on the visualization function of the front-end software, automatically generating the patient's recovery curve and risk warning prompts, and being able to conduct health intervention for high-risk patients in advance according to the risk warning prompts. For instance, Thomas Hugle [14] confirmed the feasibility of the digital nursing path by sorting out and planning the internal workflow of the hospital after digital transformation around EMR.

### 3.3 Information Management Reshaping Path

The difficulty of hospital informatization lies in the long-standing problem of interaction and data integration among "siloed" heterogeneous systems [15]. Therefore, for the efficient management and application of medical data, the deployment method of front-end software can be referred to, and the problem can be solved by building a three-level management system of data center - intelligent application - ecosystem collaboration. Firstly, a hybrid cloud architecture is adopted to build the medical data hub. The core business systems are retained for local deployment, and the data analysis layer is migrated to a dedicated medical cloud. Secondly, carry out the system transformation project, build an API gateway, encapsulate the original system into microservices, and achieve the processing of millions of data calls per day. At the same time, utilize blockchain evidence storage technology to store key medical events such as surgeries, medications, and consultations on the chain for evidence storage, ensuring data traceability. The final step is to build an intelligent application matrix, establish a clinical decision support system embedded in the specialized knowledge graph, create a resource intelligent scheduling platform for dynamic optimization of bed, equipment and human resource allocation based on reinforcement learning, and set up a scientific research data sandbox that provides data desensitization and analysis tools and accelerates the transformation of clinical research. As Radha Nagarajan [16] found, implementing large language models for medical institutions through a unified cloud service architecture is expected to promote the improvement of patient diagnosis results and operational efficiency.

### 3.4 Personnel Responsibility Reshaping Path

The traditional medical position system has problems such as a single dimension of personnel capabilities, low collaboration efficiency, and delayed emergency response. Due to the long course of treatment, high difficulty in rescue and high professional demands, the treatment of severe burns requires the participation and cooperation of multiple disciplines during the process. Establishing an integrated burn treatment system and a linkage mechanism among various institutions is of great significance for improving the homogenized treatment capacity of severe burns [17]. Therefore, against the backdrop of the in-depth application of functions such as big data analysis and intelligent model construction in front-end software, it is necessary to promote the expansion and reshaping of traditional medical job responsibilities and cultivate new types of compound position talents.

3.4.1 Clinical positions, on the basis of their original professional capabilities, add capabilities such as data interpretation and application of AI tools, and transform into clinical decision-making architects, promoting the advancement of clinical decision-making towards data and intelligence.

3.4.2 The nursing position has expanded its original nursing capabilities to include responsibilities such as Internet of Things device management and preventive nursing, becoming a smart nursing coordinator to enhance the intelligence and forward-looking nature of nursing work.

3.4.3 Administrative positions should master process modeling and resource optimization algorithms on the basis of medical quality management capabilities, and transform into operational efficiency engineers to help enhance the operational efficiency of the hospital

3.4.4 The information engineering position integrates clinical knowledge on the basis of its information technology capabilities, transforming into an expert in medical information governance to assist medical information systems in better serving clinical practice.

3.4.5 Medical technology positions will add capabilities such as AI-assisted diagnosis and predictive maintenance of equipment on the basis of the original technical capabilities, becoming intelligent medical technology analysts to enhance the accuracy of medical technology work and the level of equipment management.

### 3.5 Path for Reshaping Resource Allocation

How to rationally allocate medical resources under the background of limited medical resources is a difficult problem faced by all medical institutions. Moreover, traditional resource allocation management usually relies on the personal experience of managers and lacks quantitative data analysis, which easily leads to the waste of operating costs of medical institutions [18]. Therefore, based on the relevant functions of the front-end software, the reshaping path of hospital resource allocation can be transformed in aspects such as the allocation of hospital beds, surgeries, medical supplies, and medical staff.

3.5.1 Bed resource optimization relies on the functions of the front-end software such as case tagging, multi-source data fusion, and risk prediction models. By adding a hospitalization demand prediction model, automatic bed allocation and intelligent transfer of ICU transition wards can be achieved. At the same time, a shared bed pool for medical alliances can be constructed to transfer the demand for chronic disease beds to grassroots institutions, effectively integrating bed resources. For instance, Chen Songbin [19] proposed a data sharing model for medical alliances based on blockchain, which can effectively enhance the data access efficiency and storage space utilization rate of medical alliances.

3.5.2 Surgical resource management can be achieved through dynamic optimization algorithms, such as the honey Badger algorithm with Nash Equilibrium (HBA-NE) and the visualization model of MESS to generate an intelligent scheduling system [20], to allocate the best surgical tasks based on limited medical resources.

3.5.3 Medical supplies allocation can establish a three-level inventory system of "routine - buffer - emergency" based on the multi-source data collection and dynamic risk perception functions of the front-end software, and construct a disease transmission model in combination with artificial intelligence algorithms Dynamically optimize the storage and allocation of materials in response to three situations: seasonal diseases, clusters of high-risk diseases, and public health emergencies. For instance, Emmanuel Adeoluwa Akinluyi [21] optimized and dynamically allocated the inventory of shared medical equipment in the UK based on the COVID-19 intensive care medical equipment distribution platform, thereby matching the capacity of icus with the dynamically changing clinical demands.

3.5.4 Medical Staff Allocation: Relying on the front-end software, a disease risk-driven dynamic shift scheduling model can be established, thereby automatically generating flexible shift scheduling plans. At the same time, it can also be deeply integrated with the hospital's human resource system. For instance, the physician digital and intelligent management platform built by Zhejiang Hospital by collecting multi-dimensional data can form talent profiles through functions such as constructing tags, achieving precise matching between the capabilities of medical staff and job requirements [22].

## 4. Challenges and Countermeasures

From the perspective of technical integration, the transformation of the management model of medical institutions may encounter problems such as inconsistent data standards of multiple heterogeneous systems, for instance, there may be compatibility issues with standards like HL7, FHIR, and DICOM. For this, the OMOP-CDM general data model proposed by Christine Mary [23] et al. can be referred to for analyzing the data of different medical institution environments. In terms of organizational inertia, there may be conflicts between the goals of clinical departments and information departments in the transformation of medical institution management models. That is, clinical departments focus on improving diagnosis and treatment efficiency, while information departments pay more attention to data quality. In this regard, Kotter's "Eight-step Method for Change" can be adopted to implement two-factor incentives and build a transformation alliance to alleviate conflicts [24].

In terms of ethics, the transformation of the management model in medical institutions may encounter problems such as insufficient interpretability of AI decisions and difficulties in determining medical responsibilities. For this, the AI ethical design principles proposed by Taddeo [25] can be followed to develop dynamic responsibility division algorithms, establish a traceability chain for algorithm decisions, and ensure that its potential is utilized while reducing risks.

## 5. Summary

In conclusion, the hospital management model driven by the national intelligent monitoring and early warning software for infectious diseases is transforming from "experience-driven" to "data intelligence-driven". The transformation of its management model, in essence, is also a self-adaptive revolution for medical institutions to enter the digital medical era. It is necessary to make breakthroughs in multiple aspects such as intelligent algorithm model technology, digital literacy ability certification, and innovative data supervision systems to build a modern medical management system that combines routine and emergency care.

Author Contribution: Wang Jun: Paper writing; Yang Wei: Structural Analysis Guidance and Acquisition of Research Funds Xu Kaiwei: Review and revision.

All authors declare that they have no conflict of interest.

Data Sharing Statement: The relevant data of this paper may be obtained from the authors for reasonable reasons. Email: yongqingcdc@163.com.

Recevied: September 18, 2025;
Accepted: October 11, 2025

## References

[1] Gao GF. From "A" IV to "Z" IKV: attacks from emerging and re-emerging pathogens. *Cell*. 2018;172(6):1157-1159.doi:10.1016/j.cell.2018.02.025.

[2] Hu H, Lu JH. Responding to emerging and re-emerging infectious diseases based on the One Health strategy [published online in Chinese]. *J Sun Yat-sen Univ (Med Sci)* 2022;43(5):705-711.

[3] Deng Y, Ren X, Huang S, et al. Main research and application progress of big data in infectious disease surveillance and early warning [published online in Chinese]. *Dis Surveill*. 2022;37(8):1003-1009. doi:10.3784/jbjc.202206100255.

[4] Desjardins MR, Hohl A, Delmelle EM. Rapid surveillance of COVID-19 in the United States using a prospective space-time scan statistic: detecting and evaluating emerging clusters. *Appl Geogr*. 2020; 118:102202. doi: 10.1016/j.apgeog.2020.102202.

[5] Yang WZ, Lan YJ, Lyu W, et al. Establishment of a multi-point trigger mechanism and multi-channel surveillance and early warning mechanism for intelligent infectious disease early warning in China [published online in Chinese]. *Chin J Epidemiol*. 2020;41(11):1753-1757.

[6] Ma JQ, Wang SW, Guo Q, et al. Overall design and implementation of the national pre-software for intelligent infectious disease surveillance and early warning [published online in Chinese]. *China Digit Med*. 2025;20(3):89-95.doi:10.3969/j.issn.1673-7571.2025.03.013

[7] National Disease Control and Prevention Administration. The National Disease Control and Prevention Administration held a special press conference on "Progress and Effectiveness in Promoting the High-Quality Development of Disease Control" [published online in Chinese]. National Disease Control and

Prevention Administration website. Published December 27, 2024. Accessed March 22, 2025. https://www.ndcpa.gov.cn/jbkzzx/XWFBF/common/content/content_1873896628558614528.html

[8] Cozzoli N, Salvatore FP, Faccilongo N, Milone M. How can big data analytics be used for healthcare organization management? Literary framework and future research from a systematic review. *BMC Health Serv Res*. 2022;22(1):809. doi:10.1186/s12913-022-08167-z

[9] Undavia JN, Patel AM. Big data analytics in healthcare: applications and challenges. *Int J Big Data Anal Healthc*. 2020;5(1):19-27. doi:10.4018/IJBDAH.2020010102

[10] Li X, Shu Q, Kong C, et al. An intelligent system for classifying patient complaints using machine learning and natural language processing: development and validation study. *J Med Internet Res*. 2025;27:e55721. doi:10.2196/55721

[11] Bani-Salameh H, Al-Qawaqneh M, Taamneh S. Investigating the adoption of big data management in healthcare in Jordan. *Data*. 2021;6(2):16. doi:10.3390/data6020016

[12] Isakov TM, Laatikainen T, Kaila M, et al. From challenges to opportunities: digital transformation in hospital-at-home care. *Int J Med Inform*. 20 24;192:105644. doi:10.1016/j.ijmedinf.2024.105644

[13] Ma YY, Shen SG. The path and countermeasures to promote the modernization of the medical an d health governance system and governance capa city: based on the perspective of long-term respo nse to public health emergencies [published onlin e in Chinese]. *Humanit J*. 2020;(6):104-111. do i:10.15895/j.cnki.rwzz.2020.06.012

[14] Hügle T, Grek V. Digital transformation of an academic hospital department: a case study on strategic planning using the balanced scorecard. *PLOS Digit Health*. 2023;2(11):e0000385. doi:10.1371/journal.pdig.0000385

[15] Wang SQ, Hou ZG, Chen ZM, et al. Design of a new hospital information system [published online in Chinese]. *Chin Med Equip J*. 2022;43(3):38-45. doi:10.19745/j.1003-8868.2022053

[16] Nagarajan R, Lee H, Asress M, et al. Economics and equity of large language models: health care perspective. *J Med Internet Res*. 2024;26:e64226. doi:10.2196/64226

[17] Li XJ, Tang WB, Li SH. Practice and thinking on the integrated treatment mode for critically severe burns [published online in Chinese]. *Chin J Burns Wounds*. 2024;40(12):1101-1106. doi:10.3760/cma.j.cn501225-20240827-00317

[18] Deng L, Cheng F, Gao X, et al. Hospital crowdedness evaluation and in-hospital resource allocation based on image recognition technology. *Sci Rep*. 2023;13(1):299. doi:10.1038/s41598-022-24221-6

[19] Chen SB, Zhao M, Zhang L, Ke JL, Niu LC. Research on a blockchain-based data sharing model for medical consortia [published online in Chinese]. *Chin J Health Inform Manag*. 2023;20(1):116-121. doi:10.3969/j.issn.1672-5166.2023.01.021

[20] Xue J, Li Z, Zhang S. Multi-resource constrained elective surgical scheduling with Nash equilibrium toward smart hospitals. *Sci Rep*. 2025;15(1):3946. doi:10.1038/s41598-025-87867-y

[21] Akinluyi EA, Stell D, Perera N, Sibley-Allen C. Developing the COVID-19 intensive care medical equipment distribution platform: outcomes and lessons learned. *BMJ Open Qual*. 2021;10(2):e001383. doi:10.1136/bmjoq-2021-001383

[22] China Hospital Information Management Association. Construction and application of a human resources intelligent management platform based on talent data operation [published online in Chinese]. China Hospital Information Management Association website. Published May 5, 2023. Accessed March 22, 2025. https://www.chima.org.cn/Html/News/Articles/16108.html

[23] Hallinan CM, Ward R, Hart GK, et al. Seamless EMR data access: integrated governance, digital health and the OMOP-CDM. *BMJ Health Care Inform*. 2024;31(1):e100953. doi:10.1136/bmjhci-2023-100953

[24] Yu WP. *Organizational Change: The Guarantee for Realizing Strategic ERP Value* [published online in Chinese]. Tsinghua University Press; 2004.

[25] Taddeo M, Floridi L. How AI can be a force for good. *Science*.2018;361(6404):751-752.