A Study on the Model and Implementation Pathway of Intelligent Public Health Emergency Management

Hongpu Hu[1,a], Yanli Wan[2,b], Liqin Xie[2,c], Xingyun Lei[2,d], Yan Wang[2,e], Qingkun Chen[2,f], Yong Wang[3,g], Jianhong Yao[4,h,*]

[1]School of Marxism & School of Humanities and Social Sciences, Institute of Medical Information, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China
[2]Institute of Medical Information, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China
[3]Beijing Red Cross Blood Center, Beijing, China
[4]Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing, China

a hu.hongpu@imicams.ac.cn, b wan.yanli@imicams.ac.cn, c xie.liqin@imicams.ac.cn, d lei.xingyun@imicams.ac.cn, e wang.yan@imicams.ac.cn, f chen.qingkun@imicams.ac.cn, g wangyong7096@aliyun.com, h 2810713435@qq.com

Abstract. Since the 1970s, the outbreaks of infectious diseases caused by viruses has continued to increase, showing an accelerating trend, which seriously threatens human health and poses unprecedented external pressures on public health security. How to better respond to major epidemics and public health emergencies? How to fully utilize new technologies to achieve precise prevention and control of epidemics? That is a pressing issue. This study researches intelligent public health emergency management, discusses how to leverage the advantages of information technologies such as cloud computing, big data, artificial intelligence, the Internet of Things, and 5G to meet the practical needs of public health, and then it proposes a new emergency management model of intelligent public health. It aims to design intelligent tools and platforms based on a detailed analysis of business needs, to achieve precise prevention and control of public health emergencies. The study will also provide theoretical basis and specific implementation for enhancing the emergency response capability in public health and offer guidance to promote the construction of intelligent public health emergency management in China and even globally.

Keywords: public health, management model, implementation pathway, intelligent public health emergency management

1 Introduction

Since the 1970s, the outbreaks of infectious diseases caused by viruses has continued to increase, showing an accelerating trend, which seriously threatens human health and

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poses unprecedented external pressures on public health security. In the 21st century, with the expansion of human activities, frequent cross-border movements, and increased social activities, there are better conditions for the rapid spread of sudden acute infectious diseases, take corona viruses as an example, they have caused three large-scale epidemics: severe acute respiratory syndrome (SARS) in 2003, Middle East Respiratory Syndrome (MERS) in 2012, and Corona Virus Disease 2019 (COVID-19) in 2019. The speed of epidemic transmission, the range of infection, and the difficulty of prevention and control caused by infectious diseases have been on the rise. However, the global public health management system is still fragile, and not intelligent enough. We have insufficient capability in identifying sudden public health events, there is a lack of knowledge and model database about public health emergency events and infectious disease prevention and control and relevant information institutions is relatively backward, as a result of absence of top-level design and functional specifications. Information sharing platform has not yet been established to share information among management system for key populations, public health emergency management departments, disease control centers, medical institutions, fever clinics, and grassroots medical institutions. The intelligent public health emergency management system is not advanced enough to meet the practical needs of early warning, comprehensive assessment, and joint disposal of sudden public health events. Insufficient integration of public health emergency information and lack of information for decision-making restrict the decision-making ability, making it difficult to achieve overall resource planning for the entire society[1]. Therefore, it is urgent to tap the advantages of new-generation information technology to explore intelligent emergency management model in public health, build new platforms with intelligent multi-point triggers, comprehensive risk perception, and intelligent decision-making capability.

2 Research Progress on Intelligent Public Health Emergency Management at Home and Abroad

The optimization of intelligent public health emergency management is an important task in the construction of the public health management system. It is crucial for enhancing emergency response, strengthening risk prevention, and public health governance[2]. In terms of emergency management model and top-level design, public health emergency management model varies in different countries, which reflects that they have different decision-making priorities. For instance, the US released the "National Strategy for Biosurveillance" in 2012, aiming to establish an efficient and integrated national biosurveillance system to achieve early detection and warning of biological threats and sudden public health emergencies[3][4].The European Centre for Disease Prevention and Control's Emergency Response Coordination Centre has developed several dedicated information management tools, such as risk tracking tools for monitoring risks and conducting assessments, early warning and response systems for coordinating response actions, and infectious disease intelligence systems for implementing risk assessments.[5] In China, relevant scholars analyzed different management theories to explore the how to reform the system. For example, Li Yanjie et

al.[6] started with the key links of micro emergency management, combined with the PPRR (prevention, preparedness, response, and recovery) four-stage model of public crisis management, and improved the management system for public health emergencies from comprehensive monitoring, prevention, training capacity, preparedness, rapid response, comprehensive disposal, recovery to normalcy, improvement, and emergency situations. Chen Danqing, Ding Rongrong, and others have suggested that China's government currently implements a hierarchical and segmented management model, which presents an overall network structure with horizontal and vertical intersections [7, 8]. It is necessary to clarify the functional scope of each subject in the cross-sectoral cooperation process of sudden public health emergencies.

The research of the intelligent public health emergency management model focuses mainly on risk analysis model for sudden public health emergencies, risk prediction model, multi-source data fusion model, and infectious disease monitoring and early warning model. The main data analysis methods used include support vector machines, hidden Markov model, neural networks, decision tree model, and time series model. For example, Wang Xiao et al.[9] integrated fuzzy theory, neural networks, linear regression, and case-based reasoning methods to improve the accuracy of case-based reasoning in emergency material demand forecasting. Santillana et al.[10] combined Google search, Twitter posts, and traditional disease monitoring system data from the US Centers for Disease Control and Prevention to improve influenza surveillance. As a result Influenza-like cases report was released up to four weeks earlier than the US CDC.

In the research of intelligent public health emergency management system, data-driven approach is often used as the core to have in-depth exploration and research from various perspectives such as medical material management, medical rescue, and information coordination. For example, Holguin-Veras et al. [11]constructed an ARIMA(Autoregressive Integrated Moving Average) model based on historical data of various emergency supplies, and predicted the demand of various emergency supplies needed for Hurricane Katrina in 2005 and analyzed relevant policies. Guo Jinfen et al.[12]used the BP neural network algorithm to first predict the number of deaths and injured people caused by earthquakes, and then indirectly calculated the quantity of emergency supplies needed in the disaster-stricken area resorting to inventory management model. The researches in emergency supply demand forecasting involves artificial intelligence more and more and has gained extensive attention. Such researches aim to get a better understanding in demand estimation and emergency supply dispatching, and make more feasible emergency decisions[13].

In summary, theoretically and practically, the research in intelligent public health emergency management is only a framework or at qualitative stage, as the study on intelligent emergency management is insufficient and strategic analysis are not extensive or thorough enough, and research is mainly static, with little consideration of the real-time dynamic nature of sudden public health emergencies. The risks of sudden public health emergencies are cross-level and cross-domain in nature. There must be scientific guidance, global awareness, and systematic thinking and we must consider that these emergencies are multi-level, cross-domain, and changing rapidly. Therefore, an intelligent public health emergency management model and a digital and standard-

ized emergency management platform must be established to achieve scientific, accurate, and dynamic prevention and control and strategy and tactics. This study will focus on the development of intelligent public health emergency management from two aspects: management model and key implementation pathway. The research framework is shown in Figure 1.

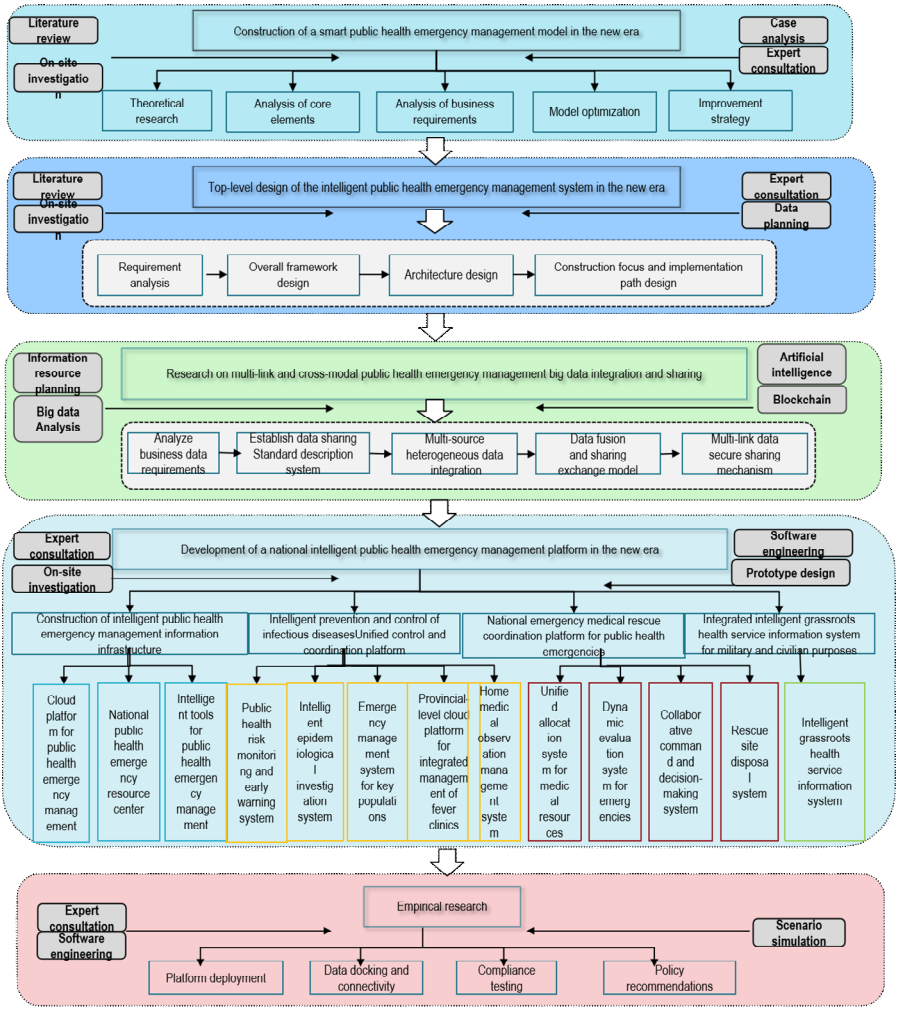

Fig. 1. Research framework.

3 Building of the Intelligent Public Health Emergency Management Model and Research on Key Implementation Pathway

3.1 Building of the Intelligent Public Health Emergency Management Mode

3.1.1 Analysis of the Core Elements.

Intelligent public health emergency management targets: public health events[14] such as infectious disease outbreaks, unexplained group diseases, acute group poisoning, and other serious health hazards caused by natural or human factors such as biology, chemistry, nuclear radiation, and so on. On the basis of sorting out the relevant theories and research results of intelligent public health emergency management, the core elements such as the connotation and extension of the intelligent public health emergency management in the new are analyzed, and the conceptual model, business model, functional model, and information model for the intelligent public health emergency management that is suitable for the new era, meets the needs of intelligent governance, and promotes the development of public health emergencies are put forward[15].

3.1.2 Building of the Management Mode.

This study is driven by both data and knowledge, starting from the four elements of holistic governance theory: objective, responsibility, integration, and institutions. Based on a comprehensive analysis of the emergency management mechanism and operational mechanism of intelligent public health, and assisted by institutional guarantees, an intelligent public health emergency management model is built through the business operation logic framework of "intelligent support - system building - goal orientation". In this mode, the goal orientation pushes forward the emergency management process and the reorganization management process from three aspects: whole space, whole period and whole process. The whole space emergency management is divided into cross-subject, cross-field and cross-region horizontal governance and multi-level and multi-department vertical governance; in the whole period emergency management, the analysis is carried out mainly from the perspective of crisis awareness and real-time response; in the whole process emergency management, the overall planned and dynamically balanced emergency management process through the whole life cycle of data is analyzed. In system building, the data flow, interactive nodes, operation processes and overall characteristics are explained through the analysis of key intelligent management processes such as visualization of monitoring and early warning, refinement of disease traceability, evidence-based judgment and decision-making, labeling of material allocation and holography of diagnosis and treatment. In intelligent support focuses on data, knowledge base, model base, technology and platform system to explore data and knowledge to achieve high efficiency, accuracy and simplicity. In-depth research on institutional guarantees is carried out in

three aspects: emergency supplies, support for scientific and technological talents, and legal protection (Figure 2).

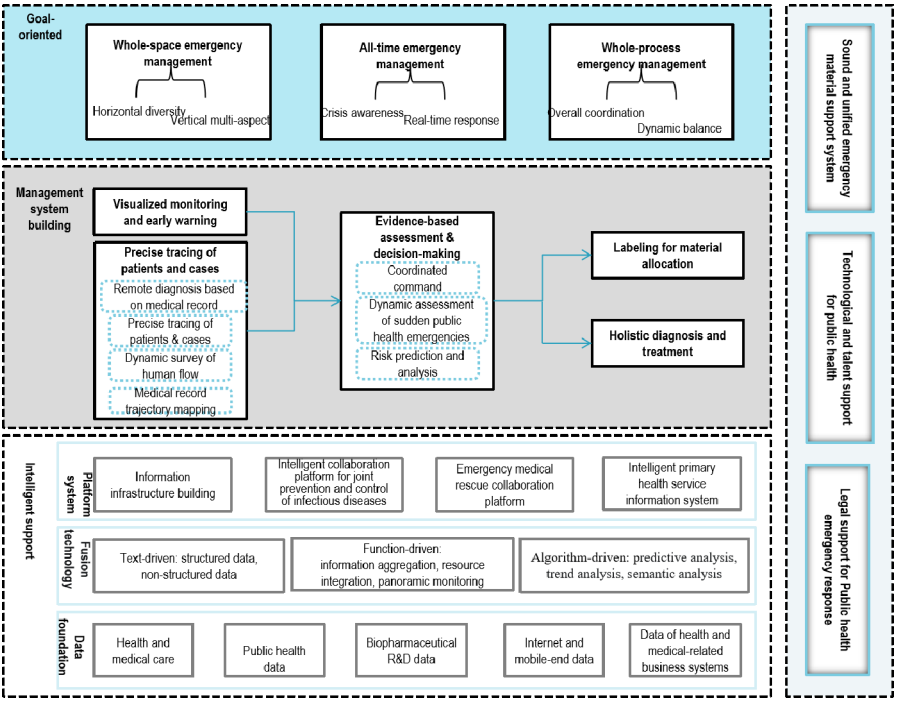

Fig. 2. Building of the intelligent public health emergency management mode.

3.2 Research on the Key Implementation Pathway of Intelligent Public Health Emergency Management

3.2.1 Top-Level Design of Intelligent Management System in the New Era.

Through literature searching, field research and expert consultation, on the basis of in-depth analysis of the current situation of public health emergency management business and information support, and in combination with the existing problems in the national intelligent public health emergency management in the new era, the needs of all levels on public health emergency management work are deeply analyzed. These needs include those from government departments at all levels, health management departments, emergency management departments, disease control departments, medical institutions, emergency medical rescue institutions, grassroots medical and health institutions, and residents. Meanwhile, the business content and process of public health emergency management in China are comprehensively sorted out; in combination with the business and information needs of all stakeholders, an overall framework for national intelligent public health emergency management in the new era is established, and the guiding ideology, basic principles, building goals and key points of intelligent public health emergency management are clarified; based on data

and knowledge planning, and combined with the actual application scenarios of intelligent public health emergency management, designs are completed on intelligent public health emergency management business architecture, management architecture, data architecture, information system architecture, infrastructure architecture, and supporting architecture, and so on; by introducing new information technologies, and clarifying key building points and implementation pathways, designs are made for key areas such as the leadership command system, the emergency command mechanism for major epidemics, the emergency response planning system for sudden acute infectious disease pandemic, the epidemic monitoring and rapid response system, the inter-departmental and inter-regional joint prevention and control mechanism, the major epidemic emergency response mechanism, the major epidemic treatment system, and the emergency material guarantee system, so as to form a top-level design of an intelligent public health emergency management system in the new era (Figure 3).

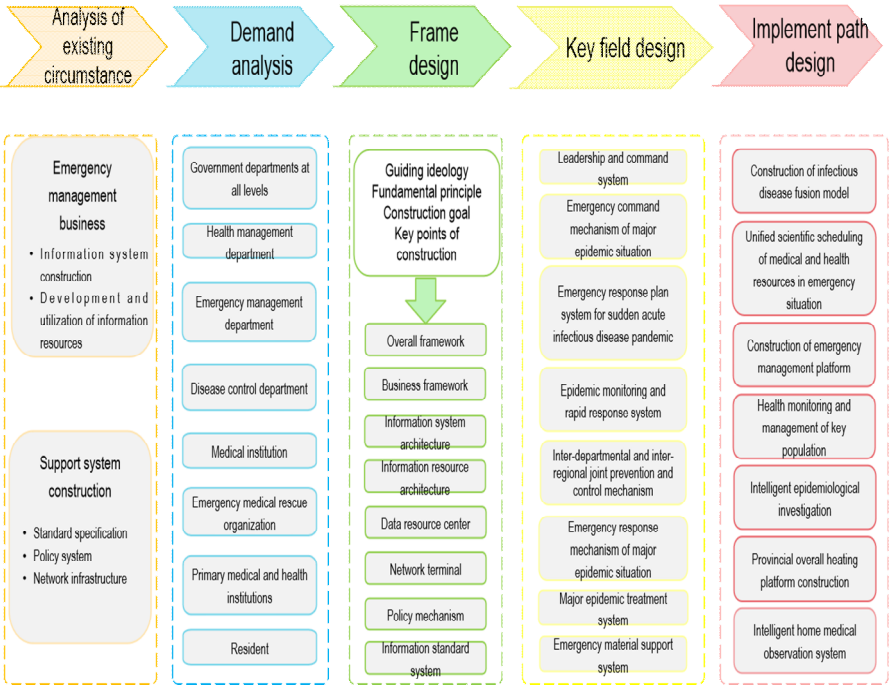

Fig. 3. Top-level design of intelligent management system in the new era.

3.2.2 Research on Multi-Link and Cross-Modal Public Health Emergency Management Big Data Fusion and Sharing.

Aiming at the problems of incomplete cross-modal and multi-link data convergence, inadequate sharing and low efficiency of data-enabled emergency management, and based on the theory of information resource planning, the multi-link cross-modal data demand of multi-party public health emergency management and

the data flow between each business are analyzed, the logical relationship and data interaction model between each business of public health emergency are sorted out, and the source, type, collection range, granularity and privacy protection level of data are determined; a standard description system of data sharing from the aspects of data format, data naming, semantic standard, disease code standard, function and building norm is established, forming a unified expression paradigm; based on ontology theory and artificial intelligence technology, researches are made on standardized processing methods and semantic analysis mining methods for public health emergency management data, an integrated multi-source heterogeneous public health emergency management data integration scheme for data layer, semantic layer, and application layer design is constructed, so as to realize data layer standardized processing and integration, semantic analysis and semantic layer integration. Meanwhile, a service library of the public health emergency management for sharing and exchange between the thematic database, the basic library and the centralized library is constructed; based on artificial intelligence, block chain and other technologies, a series of model for intelligent public health data integration and sharing exchange are studied and constructed, such as space-time intersection model, multi-source data mapping model, business system and auxiliary decision-making integration model, shared exchange model, and business collaboration model[16]; a multi-link data security sharing mechanism is established to realize the security collaborative sharing of multi-link public health emergency data (Figure 4).

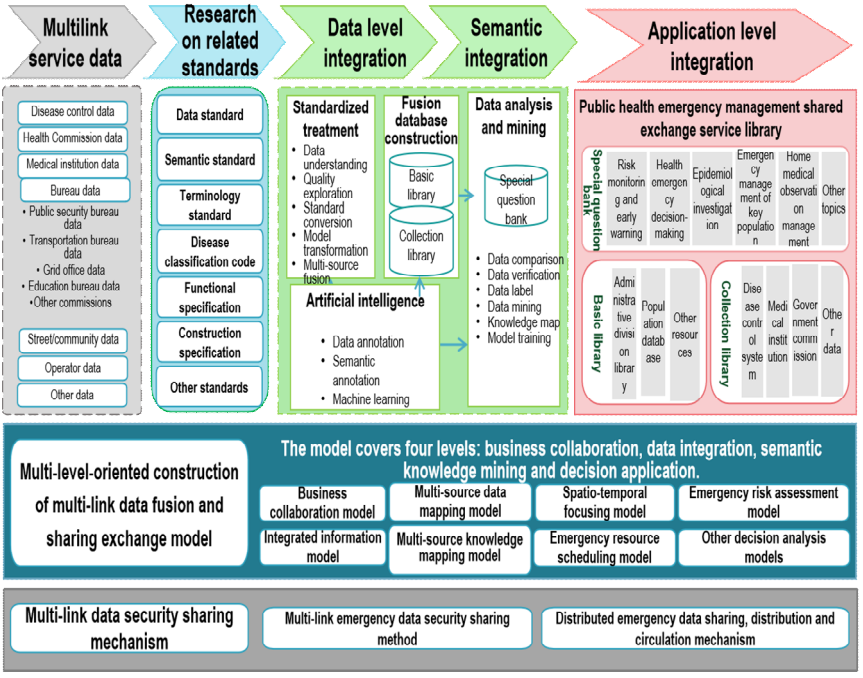

Fig. 4. Multi-link and cross-modal public health emergency management big data fusion and sharing.

3.2.3 Construction and Empirical Study of the National Intelligent Public Health Emergency Management Platform in the New Era.

Through on-site investigation, in-depth interviews, software engineering and other methods, in combination with the characteristics of the intelligent public health emergency management model in the new era, and under the guidance of top-level design, various data integration and sharing model are applied to highlight the characteristics of cross-regional, cross-departmental and cross-field collaborative disposal. The basic architecture, main functions, deployment mode, connectivity model and data architecture of the national intelligent public health emergency management platform in the new era are designed, and the design and development of the national intelligent public health emergency management platform in the new era are completed. The focuses mainly include: the building of intelligent public health emergency management information infrastructure (including public health emergency management cloud platform, national public health emergency resource center, public health emergency management intelligent tools), intelligent infectious disease joint prevention and control collaborative platform (public health risk monitoring and early warning system, intelligent epidemiological investigation system, emergency management system for key populations, provincial-level coordinated fever clinic cloud platform, home medical observation and management system), national public health emergency medical rescue collaborative platform (unified medical resource allocation system, emergency dynamic evaluation system, collaborative command and decision system, rescue site disposal system), peacetime and wartime integrated intelligent primary health services information system; different regions in the east, central and western regions are selected to carry out empirical research, and pilot applications are carried out in Beijing, Hebei, Henan, Hubei, Guangdong and Shanxi. Prototype systems are deployed, relevant institutions are connected, and users are organized for the testing and trial of platform functions. Actual business application scenarios such as fever outpatient screening, epidemiological investigation, key population management, home medical observation and management, emergency resource allocation, emergency on-site rescue are selected for simulation, so as to test and evaluate the national intelligent public health emergency management platform in the new era according to the actual business application scenarios, and optimize the system functions according to the evaluation results. Thus, a replicable and promotable national intelligent public health emergency management system for the new era and its specific implementation pathways are formed.

4 Conclusions

This study focuses on intelligent public health emergency management, aiming to propose a new intelligent management model by using information technologies such as cloud computing, big data, artificial intelligence, Internet of Things and 5G in combination with actual needs. Through detailed analysis of business needs, the corresponding smart tools and platforms are designed to strengthen the prevention and precise prevention and control of public health emergencies. This study provides the

theoretical basis and implementation path for improving the emergency response capability, and helps the development of intelligent public health emergency management in China and the world.

5 Discussion

5.1 Explore the Management Model of Forming a Benign Operation Mechanism Through Technical Support.

At present, most of the research on public health emergency management system focuses on discussing the responsibilities and rights of relevant institutions, establishing a mechanism of division of labor and coordination, and studying the countermeasures and processes of national public health emergency management. This study proposes a management model and key implementation path to enhance emergency management capabilities from multiple aspects, including disease prevention, monitoring and early warning, rescue and rescue, material support, and post recovery, through in-depth analysis of the core elements of informatization, digitization, and intelligence in public health emergency management. At the theoretical level, the smart public health emergency management mode is built through the business operation logic framework of "smart support - system construction - goal orientation", and the design of smart service business architecture, data architecture, application system architecture, infrastructure architecture, security and standard system is completed. At the implementation method level, with the goal of achieving intelligent collaboration in emergency management and integrated application of data intelligence, based on the current situation and information needs, conduct in-depth analysis of business system, information resource system, information system, network infrastructure, information standard system, etc. and carry out architecture design. Combining theory and implementation, this paper proposes development strategies for China's public health emergency management system from optimizing institutional mechanisms, improving emergency response plans, establishing emergency material coordination mechanisms, strengthening emergency equipment and facilities construction, improving guarantee mechanisms, strengthening cross departmental and cross regional cooperation, and leveraging the role of grassroots health institutions. Ultimately, the goal is to promote business collaboration and intelligent docking with vertical systems.

5.2 Conduct Top-Level Design from the Perspectives of Data Fusion, Knowledge Base Construction, Pattern Management, and System Implementation.

At present, the cross-departmental collaborative model of normalized public health emergency management has not been organically combined, and the ability of early identification of public health emergencies is generally insufficient, the integration of public health emergency information is insufficient, and the information of decision-making elements is single response to such issues, this study is problem oriented and driven by business collaboration needs. From the perspectives of data fusion,

knowledge base construction, pattern management, and system implementation, a top-level framework for designing intelligent public health emergency management is designed. Specifically, from the perspective of data fusion, a comprehensive analysis of the public health emergency management business process and data flow is carried out to achieve a comprehensive planning of the entire process of describing, collecting, processing, storing, managing, and accessing relevant data resources. Exploring the collection and integration of cross regional and cross industry data resources, and collecting various knowledge and model resources for specific applications. From the perspective of knowledge base construction, build knowledge bases such as emergency response plans, business collaboration models, emergency risk assessment models, disease diagnosis knowledge bases, and emergency resource scheduling models to support the intelligent application of the system's public health emergency management platform. From the perspective of pattern management, with information technology leading the development of the health care administration, we fully utilize emerging information technologies such as artificial intelligence and big data analysis and processing to introduce the concepts of knowledge base and model base in the risk identification, disease prevention and control, emergency response, and other aspects of traditional public health emergency management work. Through systematic design, a new public health emergency management model is formed. From the perspective of system implementation, combined with typical application scenarios, focus on developing 7 types of systems, including public health risk monitoring and warning systems, and data-driven public health emergency decision-making systems.

5.3 Intelligent Fusion and Secure Sharing of Multi-Source Heterogeneous Healthcare Data.

Aiming at effective perception, intelligent fusion and safe sharing, this paper systematically analyzes the data flow among businesses from four aspects of "prevention, control, treatment and guarantee", combs the logical relationship and data interaction between businesses, and solves the multi-source public health emergency management in an open environment. In the aspect of data integration, a series of model of intelligent public health data fusion and sharing exchange are constructed for multi-level research, covering four types of fusion model: business model, data model, semantic knowledge model and application model. Including business collaboration model, information synthesis model, multi-source data mapping model, multi-source knowledge mapping model, as well as various knowledge model and decision analysis model supporting specific application scenarios. In terms of security sharing, blockchain, distributed processing and other technologies are used to realize the distributed intelligent sharing, distribution and safe circulation of big data related to multi-link public health emergency management in an open environment, and to build a collaborative chain for monitoring and early warning of public health emergencies, a data chain for medical information security sharing, and an evidence chain for incident outbreaks.

5.4 Enhance the Intelligent Collaborative Ability of Emergency Medical Rescue with Auxiliary Decision-Making Models as the Core.

Through in-depth analysis of historical data of emergency medical rescue through artificial intelligence algorithms, mathematical modeling, simulation optimization, and the formation of emergency plan matching models, emergency material allocation models, emergency medical rescue plan models, emergency event reporting models, etc. Based on the four core auxiliary decision-making models as the underlying computing power foundation, combined with actual business processes, the research and design of the business application layer includes the research and development of a unified allocation system for medical resources, a dynamic evaluation system for emergencies, a collaborative command and decision-making system, and a rescue on-site disposal system. From this, the design of an intelligent national level public health emergency emergency dispatch and coordination platform has been completed, achieving the sharing of various medical resource information across the country, Dynamic assessment of emergencies, collaborative command, and on-site rescue response. Finally, by building a simulation platform and using scenario simulation, select 1-2 common, high-risk, and standardized emergency response events, and verify the knowledge base and decision-making model according to the normal emergency response process. [17,18]

5.5 Implementing Refined Governance Based on Key Systems.

Based on typical application scenarios, we will focus on developing public health risk monitoring and warning systems, intelligent epidemiological investigation systems, emergency management for key populations, provincial-level coordinated development of popular diagnosis cloud platforms, home medical observation management systems, and personalized intelligent grassroots health service systems, with a focus on solving refined governance methods. Among them, the public health risk monitoring and warning system, based on the constructed risk assessment and warning model for sudden public health events, timely discovers new infectious disease risks or mass public health events; The intelligent epidemiological survey system, combined with geographic information systems and the Beidou Navigation Global Positioning System, automatically obtains and integrates the past contact history of confirmed and suspected patients, and depicts the complete movement trajectory of confirmed or suspected patients. The emergency management system for key populations promotes the establishment of a linkage mechanism for key population management by integrating vital sign information, disease information, imaging test reports, internet diagnosis and treatment records, drug use, medical insurance payments, and other data of key populations. The provincial-level coordinated popular diagnosis cloud platform helps to detect infectious diseases and group diseases in the early stage, and forms a closed-loop management for fever patients. The home medical observation management system utilizes 5G, Internet of Things, and blockchain technology to interconnect intelligent wearable devices into a smart health network, providing real-time and con-

tinuous health monitoring for home observation personnel, achieving online real-time management, early warning, and behavioral intervention. Base on the integrated smart grassroots health service system achieves seamless switching between peacetime and wartime for public health emergency response through system interconnection and integration.

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