China's Health Informatization：Development, Status Quo and Challenges During COVID-19

Mian Huang, Jian Wang, Stephen Nicholas, Elizabeth Maitland, Ziyue Guo

Table of Contents

China's Health Informatization?Development, Status Quo and Challenges During COVID-19

Mian Huang[1, 2] MSc; Jian Wang[1, 2] Prof Dr; Stephen Nicholas[3, 4, 5, 6] Prof Dr; Elizabeth Maitland[7] Prof Dr; Ziyue Guo[1, 2]

[1]Dong Fureng Institute of Economic and Social Development Wuhan University Beijing CN

[2]Center for Health Economics and Management School of Economics and Management Wuhan University Wuhan CN

[3]Newcastle Business School University of Newcastle Newcastle AU

[4]Australian National Institute of Management and Commerce 1 Central Avenue Australian Technology Park Eveleigh Sydney NSW 2015 Sydney AU

[5]Guangdong Institute for International Strategies Guangdong University of Foreign Studies Guangzhou CN

[6]School of Economics and School of Management Tianjin Normal University Tianjin CN

[7]School of Management University of Liverpool Liverpool GB

Corresponding Author:
Jian Wang Prof Dr
Dong Fureng Institute of Economic and Social Development
Wuhan University
No.54 Dongsi Lishi Hutong
Dongcheng District
Beijing
CN

Abstract

Background: By applying advanced health information technology (HIT) to the healthcare field, health informatization helps optimize health resource allocation, improve healthcare services and realize universal health coverage. COVID-19 has tested the status quo of China's health informatization, revealing challenges to the health care system.

Objective: Our study analyzes the development, status quo and practice of China's health informatization, especially during COVID-19, and makes recommendations to address the health informatization challenges.

Methods: We analyzed the development of China's health informatization from five perspectives: health information infrastructure, information technology applications, financial and intellectual investment, health resource allocation and standard system, and discussed the status quo of the Internet plus healthcare service pattern during COVID-19. The main data sources included China' policy documents and national plans on health informatization, commercial and public welfare sources and websites, public reports, institutional reports and academic papers. In particular, we extracted data from the 2019 National Health Informatization Survey released by the National Health Commission (NHC) in China.

Results: China has developed its health information infrastructure and information technology applications, made significant financial and intellectual informatization investments and improved health resource allocations. Tested during COVID-19, China's status quo health informatization sytem, especially the Internet plus healthcare, has played a crucial role in monitoring and controlling the pandemic and allocating medical resources. However, an uneven distribution of health resources and insufficient financial and intellectual investment continue to challenge China's health informatization.

Conclusions: China's rapid development of health informatization has played a crucial role during COVID-19, providing a reference point for global pandemic prevention and control. To further promote health informatization, China's health informatization needs to strengthen top-level design, increase investment and training, upgrade the health infrastructure and IT applications and improve Internet plus healthcare services.

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?

✔ **Please make my preprint PDF available to anyone at any time (recommended).**

Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.

Only make the preprint title and abstract visible.

No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✔ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**

Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v

Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

China's Health Informatization：Development, Status Quo and Challenges During COVID-19

Mian Huang[12], MSc; Jian Wang[12], Prof Dr; Stephen Nicholas[3,4,5,6], Prof Dr; Elizabeth Maitland[7], Prof Dr; Ziyue Guo[12]

[1]Dong Fureng Institute of Economic and Social Development, Wuhan University, Beijing, China

[2]Center for Health Economics and Management, School of Economics and Management, Wuhan University, Wuhan, China

[3]Australian National Institute of Management and Commerce, Sydney, Australia

[4]Newcastle Business School, University of Newcastle, Newcastle, Australia

[5]Guangdong Institute for International Strategies, Guangdong University of Foreign Studies, Guangzhou, China

[6]School of Economics and School of Management, Tianjin Normal University, Tianjin, China

[7]School of Management, University of Liverpool, Liverpool, United Kingdom

Corresponding Author:

Jian Wang, Prof Dr

Dong Fureng Institute of Economic and Social Development

Wuhan University

No.54 Dongsi Lishi Hutong, Dongcheng District

Beijing, 100010

China

Phone: 86 13864157135

Email: wangjian993@whu.edu.cn

Abstract

Background: By applying advanced health information technology (HIT) to the healthcare field, health informatization helps optimize health resource allocation, improve healthcare services and realize universal health coverage. COVID-19 has tested the status quo of China's health informatization, revealing challenges to the health care system.

Objective: Our study analyzes the development, status quo and practice of China's health informatization, especially during COVID-19, and makes recommendations to address the health informatization challenges.

Methods: We analyzed the development of China's health informatization from five perspectives:

health information infrastructure, information technology applications, financial and intellectual investment, health resource allocation and standard system, and discussed the status quo of the Internet plus healthcare service pattern during COVID-19. The main data sources included China' policy documents and national plans on health informatization, commercial and public welfare sources and websites, public reports, institutional reports and academic papers. In particular, we extracted data from the 2019 National Health Informatization Survey released by the National Health Commission (NHC) in China.

Results: China has developed its health information infrastructure and information technology applications, made significant financial and intellectual informatization investments and improved health resource allocations. Tested during COVID-19, China's status quo health informatization sytem, especially the Internet plus healthcare, has played a crucial role in monitoring and controlling the pandemic and allocating medical resources. However, an uneven distribution of health resources and insufficient financial and intellectual investment continue to challenge China's health informatization.

Conclusions: China's rapid development of health informatization has played a crucial role during COVID-19, providing a reference point for global pandemic prevention and control. To further promote health informatization, China's health informatization needs to strengthen top-level design, increase investment and training, upgrade the health infrastructure and IT applications and improve Internet plus healthcare services.

Keywords: health informatization; COVID-19; health policy; health information technology; China

Introduction

China's accelerating population aging and rising living standards has placed new demands for high-quality healthcare services on the world's largest hospital and health system [1]. One challenge facing China's health system is the uneven distribution of medical resources [1-3]. Building on China's highly developed information-based society, including big data, cloud computing, mobile Internet and artificial intelligence (AI), health information technology (HIT) provides a key impetus for the Chinese government to maximize health resource allocation, ensure China's universal health coverage and enable healthcare providers to optimize healthcare services with lower medical costs and better quality [4-6].

Health informatization in China has developed through several stages, and the policy system at every stage has sought consistency and coordination. In 2010, the National Health and Family Planning Commission (NHFPC) issued the "3521 framework" for health informatization, which was then upgraded to the "4631-2 framework" in 2013 [7-10]. As is shown in Figure 1, the "4631-2 framework" referred to four-levels of national health information platforms (national, provincial, municipal and county level), six primary applications (public health, medical service, medical insurance, drug administration, family planning and integrated management), three major health information databases (the demographic information database, the electronic health record database and the electronic medical record database), one unified network covering all kinds of healthcare institutions (including traditional Chinese medical institutions) and two systems (population health information standard system and information security system) [8,11].

Figure 1. The 4631-2 framework of health informatization.
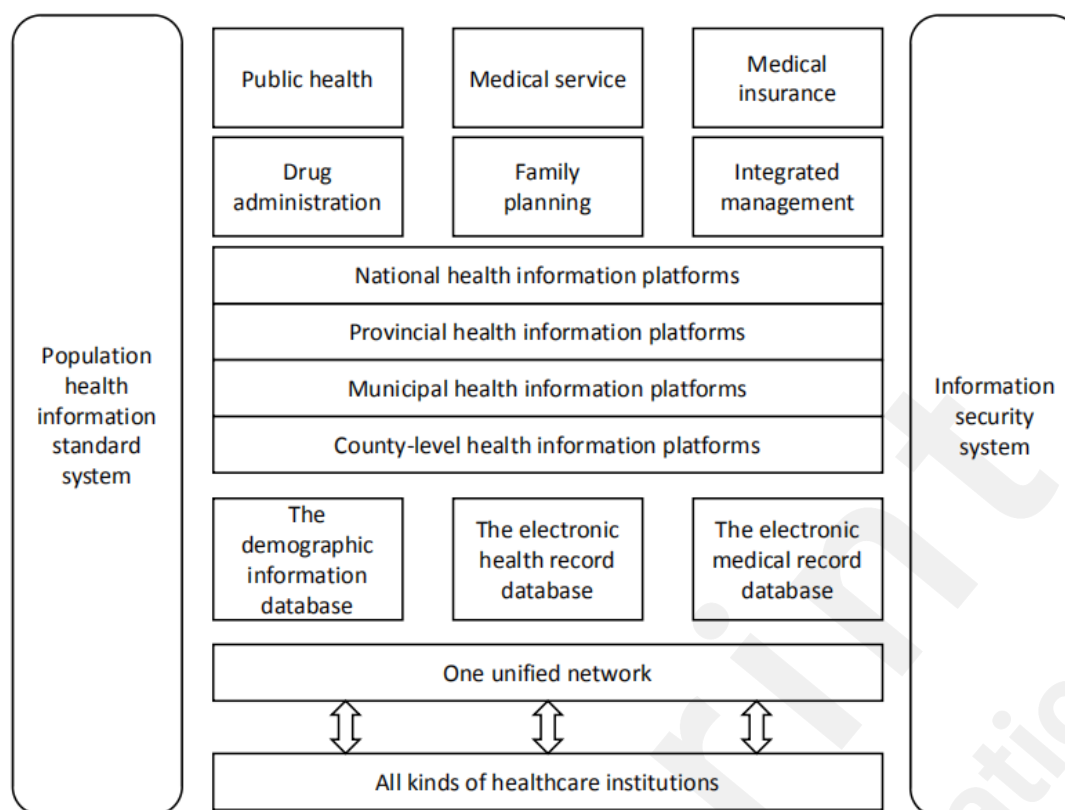
Building on the 4631-2 framework of health informatization, the 2016 Plan of Healthy China 2030 committed to expanding the health information service system. The NHFPC released National Population Health Informatization Development Plan in 2017, emphasizing the essential role of health informatization in national IT construction, health reform and the Healthy China initiative [12]. In 2018, the National Health Commission (NHC) was established, further emphasizing the role of health informatization by targeting comprehensive and lifelong intelligent health services through utilizing advanced technologies. The 2021-2025 14th Five-year Plan period is expected to further improve health services, especially in the COVID-19 context, where health informatization will be further promoted.

Surprisingly, the development of the health informatization system has not been detailed and the status quo effectiveness of China's health informatization assessed. The early COVID-19 period, when HIT played a crucial role in the prevention and control of the pandemic, provides an opportunity to assess China's health informatization [13]. During COVID-19, extensive use of Internet plus healthcare, including Internet hospitals and telemedicine, provided timely and convenient medical services to ensure a normal operation of the medical system [14,15]. Medical big data helped monitor and forecast pandemic trends, enhancing China's COVID-19 prevention ability. However national health informatization is incomplete in China. The uneven distribution of health resources remains a challenge [1,3], with further investment in HIT required to complete the health informatization system and realize universal health coverage. Our paper maps the development of China's health informatization; asseses China's status quo health informatization experiences and lessons during COVID-19; identifies the challenges to health informatization; and advances suggestions for the improvement of health informatization.

Methods

In order to evaluate the status quo of health informatization and to provide data for the further development of China's health informatization, the NHC conducted a 2018 survey on national health informatization, with the National Health Informatization Survey Report published in 2019 [16]. The Survey can be divided into two parts: regional health informatization and hospital informatization. The Regional Health Informatization Survey covered 1650 health commissions (HCs), including all 32 provincial HCs, 69.6% (296/425) of municipal HCs and 47.1% (1322/2803) of county-level HCs. The Hospital Informatization Survey covered 5470 hospitals, including 70.1% (1480/2112) of tertiary hospitals, 62.1% (3730/6004) of tertiary hospitals, and 6.2% (260/4180) of other hospitals (at lower levels). The survey identified key aspects of health informatization, including infrastructure, IT application, capital investment and human resources, providing data for assessing the status quo of China's health informatization.

Figure 1 sets out a diagrammatic representation of the conceptual basis of China's health informatization, while Table 1 summarizes the main data sources from government, commercial and public welfare sources and websites, academic papers, public reports, institutional reports and fieldwork used to outline the development and evaluate the status quo of China's health informatization.

Table 1. Data sources on the development and status quo of China's health informatization from government, commercial and public welfare sources and websites, academic papers, public reports, institutional reports and fieldwork.

Perspective	Contents	Data sources
Health information infrastructure	Development of health information platforms and health information databases	Policy documents published by the Ministry of Health, the National Health and Family Planning Commission (NHFPC) and the National Health Commission (NHC) in China
		NHFPC's National Population Health Informatization Development Plan
		China's 13th Five-Year Plan
		The Plan of Healthy China 2030
		Researches from the Center for Health Statistics and Information, NHFPC
		Academic papers
	The construction rate of provincial, municipal and county-level health information platforms	2019 National Health Informatization Survey Report published by the NHC
		2018 Regional Health Informatization Survey
	The average construction rate of three major databases	2019 National Health Informatization Survey Report published by the NHC
		2018 Regional Health Informatization Survey
Information technology applications	The development history of health informatization in China	Outline of National Health Informatization Development Plan 2003-2010
		NHFPC's National Population Health Informatization Development Plan
		China's 13th Five-Year Plan
		Policy documents published by the Ministry of Health, the NHFPC and NHC in China
		Researches from the Institute of Medical Information, Chinese Academy of Medical Sciences
		Academic papers
	IT application rates on health information platforms and in hospitals	2019 National Health Informatization Survey Report published by the NHC
		2018 Regional Health Informatization Survey
		2018 Hospital Informatization Survey
	IT applications in COVID-19 prevention and control	News, reports and information from health authorities, hospitals, and high-tech companies including Baidu, Alibaba and Tencent

A

		Academic papers
Financial and intellectual investment	Governmental investment	China's 12th Five-Year Plan
		2017 National Health Informatization Survey conducted by the NHFPC
		National Health Security Informatization Project approved by the National Development and Reform Commission
		National hospital informatization projects approved by the NHFPC
		Policy documents released by the Ministry of Finance, the NHFPC and the NHC in China
		Researches from Center for Health Statistics and Information, NHC
		NHFPC's National Population Health Informatization Development Plan
		China's 13th Five-Year Plan
		2019 China Health Statistical Yearbook
	Hospital informatization investment	Policy documents published by the NHC
		Researches from Center for Health Statistics and Information, NHC
		2019 National Health Informatization survey report published by the NHC
		2018 Hospital Informatization Survey
		2019 CHIMA (China Hospital Information Management Association) survey
	The quantity and quality of health informatization personnel in information departments of administrations and hospitals	2019 National Health Informatization survey report published by the NHC
		2018 Regional Health Informatization Survey
		2018 Hospital Informatization Survey
		NHFPC's National Population Health Informatization Development Plan
		China's 13th Five-Year Plan
		Academic papers
Health resource allocation	The construction strategies of health informatization	Policy documents published by the State Council of the People's Republic of China
		Researches from the Center for Health Statistics and Information, NHFPC Academic papers

	Medical resource allocation during COVID-19	News, reports and information from websites of the NHC and hospitals
		Academic papers
Standard system	The development history of standard system	NHFPC's National Population Health Informatization Development Plan
		China's 13th Five-Year Plan
		Policy documents published by the Ministry of Health, the NHC, and the Special Committee on Health Information Standards
		The National Medical Health Information System's Interconnection and Interoperability Standardization Certification
	The formulation of information standard system and security system	2019 National Health Informatization survey report published by the NHC
		2018 Regional Health Informatization Survey
		2018 Hospital Informatization Survey
		2018 National Medical Health Information System's Interconnection and Interoperability Standardization Certification
		2017 National Medical Health Information System's Interconnection and Interoperability Standardization Certification
		Policy documents published by the NHC
	The evaluation of information standard system and security system	2019 National Health Informatization survey report published by the NHC
		2018 Regional Health Informatization Survey
		2018 Hospital Informatization Survey
	Reforms of national health information standardization system during COVID-19	The 2020 Notice on Strengthening the National Health Information Standardization System
		National Public Health Informatization Construction Standard and Specification
		National Hospital Informatization Construction Standard and Specification
		Policy documents published by the NHC
Internet plus healthcare	The applications and achievements of	Information from the NHC's press conference

| service pattern | Internet plus healthcare in COVID-19 | News, reports and information from health authorities, hospitals, and high-tech companies including Baidu, Alibaba and Tencent |
| | | Academic papers |

In the next section, the data from Table 1 are used to analyze the development of China's health informatization from five perspectives: health information infrastructure, information technology applications, financial and intellectual investment, health resource allocation and standard system.

Results

Development of Health Information Infrastructure

China's health information platforms form the basis of China's regional health informatization. In 2012, the Ministry of Health in China proposed a three-level (national, provincial and regional) health information platform [9]. As displayed in Figure 1, the health information platform was extended in 2013 to consist of four administrative level platforms: the national, provincial, municipal and county-level information platforms [10]. On each platform, the medical data from different regions were integrated and shared [7]. The platforms were designed to be unified, authoritative and interconnected so as to exploit and statistically analyze health information of the whole population, thus providing support for management and decision-making on a national health level [12,17,18]. The platforms also provided the basis for an information business system covering the whole industry chain of health and medical big data, linking medical care, medical insurance and medicine. By 2018, 93.8% (30/32) of provincial health information platforms, 66.2% (196/296) of municipal health information platforms, and 48.2% (637/1322) of county-level health information platforms had been established [16]. During COVID-19, by sharing data with internet hospitals and healthcare institutions at all levels, regional health information platforms connected online and offline services to provide patients with full process services before, during, and after diagnosis [19,20]. During the COVID-19 period, the NHC promoted new infrastructure construction in health informatization, emphasizing the need to improve health information platforms and health information databases [19].

National health information databases include three major databases: the demographic information database (DID), the electronic health record database (EHRD) and the electronic medical record database (EMRD). The DID contains fundamental population information, family planning service management information, and the non-resident population management information. The EMRD stores all information from electronic medical records while the EHRD holds residents' personal health information from the electronic health record (EHR), which is defined as "digitally stored health care information about an individual's lifetime with the purpose of supporting continuity of care, education, and research and ensuring confidentiality at all times" [7,21]. The 2010 "3521 framework" contained only two databases: the EHRD and the EMRD [22], with DID added under the 2013 "4631-2 framework". [23].

The three major databases are relatively independent, but interrelated. Supported by the national health information platform, information in the three databases is shared and dynamically updated to ensure consistency, accuracy and integrity of the information [12,24]. According to the 2019 National Health Informatization Survey, the average construction rate of EHRDs was 79.5% (1312

out of 1650 HCs had built EHRDs), the highest among the three databases, with 93.8% (30/32) of provincial, 84.8% (251/296) of municipal and 78.0% (1031/1322) of county-level EHRDs. The average construction rate of the DIDs was 77.5% (1278 out of 1650 HCs), with 100% (32/32) of provincial, 80.4% (238/296) of municipal and 76.2% (1008/1322) of county-level DIDs. Lowest among these three databases, the average construction rate of EMRD was 49.5% (816 out of 1650 HCs), which was 93.8% (30/32) of provincial and 59.5% (176/296) of municipal and 46.1% (610/1322) of county-level EMRDs [16].

Development of Information Technology Applications

With the development of technology applications, Figure 2 sets out the four development stages in China's health informatization: the early stage from 1980s to 2003; the exploratory stage from 2003 to 2009; the rapid development stage from 2009 to 2016; and the innovation stage since 2016 [25,26]. In the early stage (1980s-2003), the emphasis was placed on the application of computer technology in information systems, such as the financial management system and charging system, in large medical institutions. Manual operations were replaced by computer functions in the management of traditional businesses, including financial management, fee management and drug management. At the exploratory stage (2003-2009), drawing on the experience of SARS in 2003, China strengthened its informatization in health emergency command, disease prevention and control, public health resources and health information management [27]. Importantly, a direct internet reporting system for infectious diseases and public health emergencies was established, and regional health informatization emerged. In the context of healthcare reform, the rapid development stage (2009-2016) completed the construction of the national health information platform and database, dealing with the information islands in health services as well as realizing the platform connectivity and information sharing of the medical and health systems. Since 2016, more advanced information technologies, such as internet plus, big data, cloud computing and artificial intelligence have been widely applied to health industries. In the innovation stage, a people-centered medical service principle was adopted [28], with advanced IT applications improving the health information system and providing more diverse health information services [12].

Figure 2. The development history of health informatization in China.
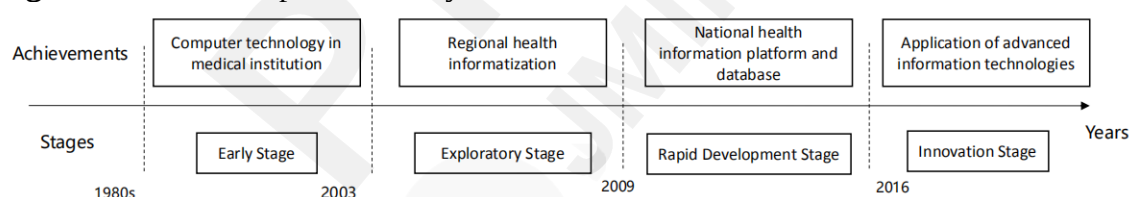
Currently, advanced technologies commonly used in China's health informatization include cloud computing, big data, internet of things, mobile internet, and artificial intelligence. The 2019 National Health Informatization Survey showed that advanced technologies, especially mobile Internet and big data, were more commonly applied on provincial, than municipal and county, platforms. In 2018, on provincial health information platforms, the application rate of cloud computing was 68.8% (22 out of 32 provinces), big data was 53.1% (17 out of 32 provinces), internet of things was 21.9% (7 out of 32 provinces), mobile internet was 71.9% (23 out of 32 provinces), and artificial intelligence was 12.5% (4 out of 32 provinces). On municipal and county-level platforms, advanced technologies were less utilized, where 40.2% (119/296) of municipal and 46.1% (609/1322) of county-level platforms had not utilized any advanced technologies [16]. Higher-level hospitals had higher IT application rates, with mobile internet the most commonly used technology (50.5% or 747 out of 1480 tertiary hospitals; 20.6% or 767 out of 3730 secondary and 24.2% or 63 out of 260 other

hospitals), and artificial intelligence the least used technology (9.3% or 137 out of 1480 tertiary hospitals; 1.7% or 62 out of 3730 secondary hospitals and 1.2% or 3 out of 260 other hospitals).

COVID-19 tested the informatization of China's health system. In COVID-19 prevention and control, advanced information technologies were effectively utilized in monitoring and forecasting the pandemic's trends as well as constraining the spread of the virus. Based on big data, the intelligent risk assessment system and automatic early warning system were utilized to fight the virus. Big data was used to track the mobility of the population and locate crowds after the outbreak. With the help of artificial intelligence, the number of infections was estimated, and high-risk areas identified, which helped the government to implement timely control methods and determine the allocation of resources [29]. Using a series of data statistics and model analysis, big data population movement information on Baidu Maps was one of the most popular technologies to estimate the number and locations of COVID-19 patients and carriers. The big data methods also predicted the virus' trends based on real-time reporting of new cases.

In order to improve data utilization, some hospitals promoted the connection between hospital information systems and regional health information platforms. Hospital information departments extracted data from major information systems such as Hospital Information System (HIS), Laboratory Information System (LIS), Picture Archiving and Communication Systems (PACS) and Electronic Medical Record (EMR) to build a clinical data center [30,31]. An induction model based on AI was constructed to help predict the risk and trend of infectious diseases and enhance the prevention ability [1].

Development of Financial and Intellectual Investment

From Table 1, the importance of health informatization can be assessed by China's increased levels of investment. During the 2011-2015 12th Five-Year Plan, the central government invested more than ¥10 billion (US$1.5 billion) into health informatization [7]. In 2017, the first phase of the National Health Security Informatization Project was approved by the National Development and Reform Commission, with ¥340 million (US$52.5 billion) invested in national platform construction; 32 national hospital informatization projects approved by the NHFPC; and ¥310 million (US$47.9 million) invested by the NHFPC in the construction of information platforms and clinical data centers [32]. In 2018, the Ministry of Finance invested ¥670 million (US$103.5 million) to equip 832 poor county hospitals and 1,664 primary-level medical institutions with telemedicine equipment. In 2019, the central government allocated ¥180 million (US$27.8 million) to increase technology applications including the internet, big data and artificial intelligence in nine provinces, improving the diagnosis and treatment capacity of family doctors [33].

Although governmental investment in health informatization expanded rapidly, it failed to cover China's current financial informatization needs, reflecting a lack of stable and sustainable capital input. For example, China's health expenditure accounted for 7.56% of financial expenditure, while health informatization expenditures accounted for only 0.7% of total health expenditure [34]. Second, there were obvious regional differences in governmental investment, with Beijing, Guangzhou, Shanghai and eastern coastal provinces achieving rapid development of health informatization versus the less developed provinces [35]. The capital input in informatization was positively associated with the local economic development level, where informatization tended to increase regional health inequality [16]. The 2019 National Health Informatization Survey showed that hospital informatization investment was limited. The proportion of informatization investment in

a hospital's annual revenue was between 0.1% and 1% in 67.3% (3681/5470) of hospitals and 1%-5% in 23.7% (1296/5470) of hospitals, with only 3.7% (202/5470) of hospitals investing over 5% of their annual revenue in informatization. With the construction of health informatization requiring multi-sectoral collaboration, the lack of social supervision led to lack of initiative and a waste of resources. In 2017, according to the China Hospital Information Management Association (CHIMA) survey, hospital self-raised funds accounted for 68.8% of the total investment in hospital informatization, with government financial funds accounting for 28.4% and other funds accounting for 2.8% of total investment [36,37]. Although the Chinese government has implemented policies to encourage enterprise initiative, an incentive mechanism to encourage social capital to participate in health informatization construction has not been set up in China. Measures to promote government-enterprise cooperation in health informatization are still being explored [12,38].

Both the quantity and quality of technical informatization personnel failed to meet demand [12]. The number of health informatization personnel was small. In 2019, the average staff number in provincial information departments was only 20, while 91.6% (271/296) of municipal information departments and 93.6% (1238/1322) of county-level information departments had less than 9 informatization staff. In hospitals, the information department of tertiary hospitals had on average 10 staff, while 74.1% (2764/3730) of secondary hospitals and 89.5% (233/260) of other hospitals had less than 4 informatization staff. In particular, there was a lack of highly educated and specialized informatization personnel and an uneven distribution of high-quality personnel in administration and hospitals at different levels [39]. High-level administrations and hospitals tended to have staff with higher education [16], with the proportion of staff with bachelor degrees or above in provincial information departments (88.9%) and in municipal information departments (83.8%) significantly higher than that in county-level information departments (51.6%). Information departments in tertiary hospitals had 67.5% of their staff with bachelor degrees, while in secondary and other hospitals, most staff had degrees below the junior college level. The proportion of staff with master's degree or above in tertiary hospitals (14.3%) was significantly higher than that in secondary hospital (2.3%) and in other hospitals (0.7%). Staff specialized in computer science accounted for 85.1% of informatization staff in tertiary hospitals compared to 49.1% in secondary and 26.5% in other hospitals. In addition, IT staff with senior professional titles were scarce in all types of hospitals, with only 2.0% in tertiary, 1.9% in secondary and 0.6% in other hospitals [16].

Development of Health Resource Allocation

Medical resources distribution and health service capacity were unevenly distributed regionally and by type of medical institution [3,4]. The data from Table 1 reveals that the construction strategies of health informatization varied according to the healthcare resource allocation status in different regions [1].

For the developed, mainly eastern coastal, regions with abundant medical resources, the local health administration undertook the major responsibilities for integrating high-quality medical resources and promoting health informatization. These regions had stronger abilities to independently develop informatization and provide stable and sufficient funds for informatization. Bottom-up building of health information platforms and data centers were established by the local health administration to connect the information system of health institutions at all levels in the administrative region, achieving the sharing and exchange of medical information. For example, municipal and county-level health commissions in each province independently carried out informatization construction, driving the development of provincial health informatization and promoting the development of regional health information infrastructures, information technologies and professionals. Municipal and county-level health resource information was integrated and the connectivity of health

information within the province was realized [22].

In developing regions, mainly in western and central China, where medical resources were scarce, large hospitals were generally taken as the center to connect with several local primary healthcare institutions to realize medical information exchange and sharing [22]. For instance, the West China Hospital of Sichuan University cooperated with surrounding secondary hospitals and community health service centers to realize regional medical collaboration. Shengjing Hospital of China Medical University, in cooperation with public hospitals at all levels in Liaoning and Shenyang, constructed Shengjing Medical Alliance, a non-profit medical cooperative alliance. In these less developed and health resource scarce regions, unified management was implemented within the medical alliances to integrate medical resources at different levels. To optimize medical resources, resource poor regions utilized telemedicine, or the use of telecommunications technologies to provide medical information and services, [1,4,40] for remote consultation and two-way referral, where primary medical units can get support from large hospitals and gain access to high-quality medical resources and services.

The COVID-19 pandemic typically led to a surge in demand for medical care, which overwhelmed local capabilities [41,42]. During the pandemic, telemedicine played an increasingly important role in medical resource allocation. [1,4,40] As the worst-hit area of COVID-19 in China, Hubei province's medical institutions were overloaded with a severe shortage of medical resources and services [41]. Due to the implementation of control measures such as lockdown, traffic control, and community closure management, residents' access to healthcare resources was severely restricted. Telemedicine was widely used to overcome geographical barriers and expand the supply of medical resources [43-45]. With the aid of informatization technologies, many doctors from other parts of China provided remote diagnosis and treatment services. For instance, the medical team from Guangdong province built an Internet hospital to provide online clinical support for patients in Jingzhou city, Hubei province. More than 1,300 doctors from 15 medical institutions in Guangdong participated, with the total number of online visitors exceeded 100,000 within 18 days of its launch, making up for local medical service deficits in Hubei province [46].

Development of Standard System

From Figure 1 and Table 1, emphasis has been placed on the standardization of health information, or the standard system [12]. In 2006, the Special Committee on Health Information Standards was approved by the Ministry of Health, where work on health information norms were standardized. Started in 2012, the National Medical Health Information System's Interconnection and Interoperability Standardization Certification [16] aimed to strengthen the management and promote the implementation of health information standards, so as to achieve health information interoperability [11]. The Regional Health Informatization Survey and Hospital Informatization Survey found that by 2017, 54 regional platforms (1 provincial platform, 45 municipal platforms and 8 county-level platforms), and 90 hospitals (84 tertiary hospitals and 6 secondary hospitals) had been certified. Between 2018 and 2019, the number certified significantly increased with an additional 48 regional platforms and 101 hospitals certified [47]. By 2018, all provincial platforms, 90.9% (269/296) of municipal platforms and 78.9% (1043/1322) of county-level platforms had formulated an information security system. Meanwhile, 99.2% (1468/1480) of tertiary hospitals, 95.9% (3577/3730) of secondary hospitals and 81.5% (212/260) of other hospitals had formulated an information security system. By August 2020, with 227 effective information standards approved, the standard system for regional health informatization and hospital informatization had been basically established throughout the health system [24].

During COVID-19, continuing shortcomings in the standard system were addressed by the 2020 Notice on Strengthening the National Health Information Standardization System, which defined four key tasks for the construction of the national health information standardization system. First, to promote the standardization of the national health information infrastructure, including the national health information platform, national hospital information platform, government services integration platform, and to standardize the information from grassroots health institutions, public health systems and traditional Chinese medicine hospitals. Second, to strengthen the standardization of the national demographic information database (DID), the electronic health record database (EHRD), the electronic medical record database (EMRD) and the healthcare resource database. Third, to promote the standardization of advanced IT applications, comprising five technologies: internet plus healthcare, health and medical big data, healthcare artificial intelligence, healthcare 5G technology, and blockchain technology for healthcare. Fourth, to improve the standardization of network security, namely industry network security standard system, data security standard, and industry application security standard. In order to improve the disease prevention and control system and enhance the ability of responding to public health emergencies, the NHC formulated on December 11 2020 the National Public Health Informatization Construction Standard and Specification to further regulate national public health informatization, specifying 21 first-level indicators, 125 second-level indicators and 421 third-level indicators of health service management and IT application content in all types of health institutions [24].

Even with these reforms, shortcomings in China's health information standard system remain. There was a lack of standard evaluation, and the consistency and interoperability of the standard system needed strengthening [1]. The formulation of China's standard system lagged behind the development of new technologies. The safety standards, data standards, functional standards, quality assessment standards for information technology products, and management standards for data quality, were incomplete. In terms of information security standards, the ownership and use rights of patients' health information, and the rights and responsibilities division among all parties, needed further clarification in laws and regulations. There was a lack of security standard evaluation. The Regional Health Informatization Survey reported that in 2018, 75.0% (24/32) of provincial platforms, 30.4% (90/296) of municipal platforms and 17.7% (234/1322) of county-level platforms had implemented the evaluation of classified information security protection. Only 46.4% (687/1480) of tertiary hospitals, 18.6% (694/3730) of secondary hospitals and 10% (26/260) of other hospitals had participated in the evaluation. Although China continues to develop health information standards, due to the large number of departments involved, many standards and norms were not unified. There were also problems such as unclear management responsibility for the standards and ineffective supervision mechanism [11].

Discussion
Our development and assessment of China's health informatization system identified both key status quo elements in the healthcare services sytem, as outline in Figure 3, and challenges to the healthcare system in post-COVID-19 China.

Status quo of Internet Plus Healthcare Service Pattern during COVID-19

As shown in Figure 3, the new service pattern of Internet plus healthcare sought to meet the increasing medical demands and virus prevention and control during the COVID-19 pandemic.

Figure 3. The applications and achievements of Internet plus healthcare in COVID-19.
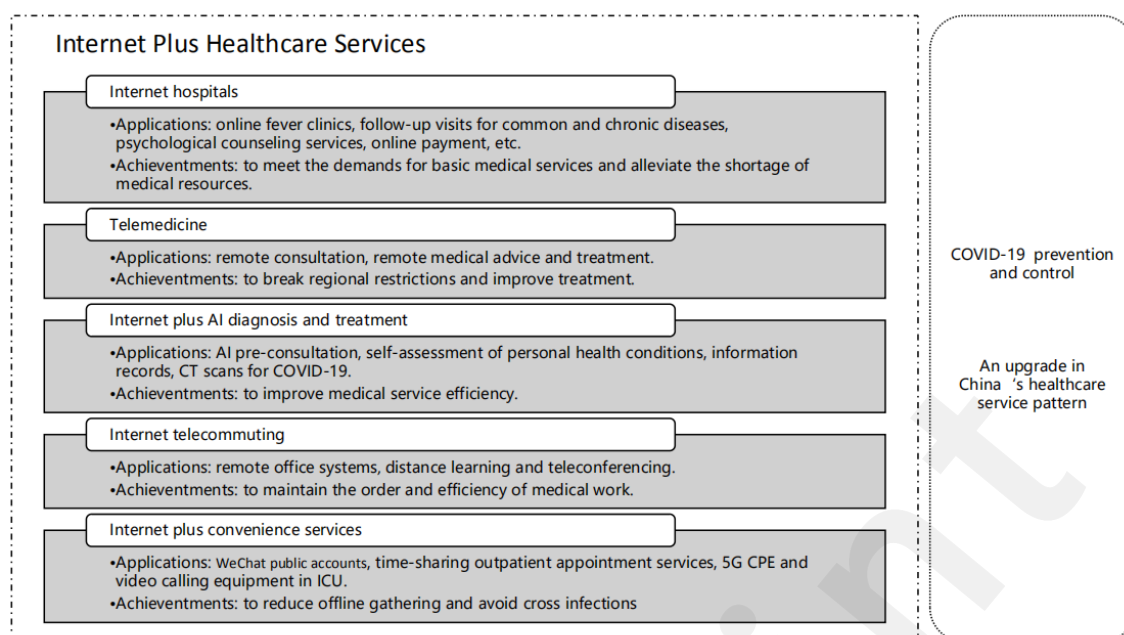
Internet plus healthcare has the characteristics of remoteness, efficiency, intelligence and convenience, providing online consultation, remote diagnosis, psychological counseling, chronic disease follow-up, and drug distribution to meet people's medical demands. [38,46]. During COVID-19, Internet plus healthcare aimed to break through time and space constraints to both identify and service infected people, block transmission routes and reduce the risk of population infection. The popularization of Internet plus healthcare has not only improved the efficiency of healthcare institutions at all levels [48], but also stimulated innovation and accelerated the upgrading of China's healthcare service pattern. We set out below the contours of Internet plus healthcare during the COVID-19 pandemic.

Internet hospitals: to meet the demands for basic medical services and alleviate the shortage of medical resources during COVID-19

After the COVID-19 outbreak, Figure 3 identifies the role of internet hospitals and online fever clinics, which were widely established to provide follow-up visits for common and chronic diseases, as well as psychological counseling services. In an internet hospital, a full set of medical services such as registration, consultation, diagnosis and prescription were completed by means of video, voice and graphic communication [49]. Hospitals arranged drugs delivery, while patients made online payments [50]. By effectively serving a large number of COVID-19 patients, Internet hospitals reduced diagnosis and treatment pressure in brick-and-mortar hospitals, greatly alleviating the shortage of medical resources in severely affected COVID-19 areas.

Telemedicine: to break regional restrictions and improve treatment during COVID-19

As specified in Figure 3, remote consultation through the telemedicine platform integrated high-quality medical resources and provided support from large institutions and famous experts to improve treatment. Due to the uneven distribution of medical resources in different regions, China attached great importance to constructing a telemedicine system, which played a particularly significant role during the pandemic. As discussed above, a typical case was the establishment of nine telemedicine centers in Guangdong province to support the hard-hit COVID-19 city of Jingzhou. While on-site diagnosis was carried out, remote medical advice and treatment were provided via the telemedicine platform at the same time.

Internet plus AI diagnosis and treatment: to improve medical service efficiency during COVID-19

Online artificial intelligence pre-consultation functions were widely used to assess COVID-19 risks and provide emotional care, as shown in Figure 3. People made a self-assessment of their personal health condition with the help of AI technologies, where patients provided their personal information, past medical history and current medical conditions through dialogue before seeing a doctor. This information was recorded by AI and integrated into the health information system, then directly added into the patient's medical record to facilitate subsequent diagnosis. Artificial intelligence was also applied to CT scans for COVID-19, improving the accuracy and efficiency of front-line medical work [29].

Internet telecommuting: to maintain the order and efficiency of medical work during COVID-19

As noted in Figure 3, distance learning and teleconferencing had become mainstream working modes during the pandemic. Many hospitals used Virtual Private Network (VPN) technology to establish secure data links, and combined with Virtual Desktop Infrastructure (VDI) technology, a remote office environment was built. By opening the VPN account and private cloud desktop, the remote office system enabled medical staff to log into the intranet workstations to work remotely [51].

To enhance service ability of medical staff, distance education was also used widely during the pandemic. Learning content was issued on online learning platforms. To check learning effects, medical staff were required to take regular online tests, and test results were recorded in real time. Moreover, IT companies such as Tencent and Alibaba, launched free online meeting systems to support anti-pandemic work, enabling the pandemic prevention working groups to arrange work, discuss diagnosis methods and pandemic prevention countermeasures through video conferencing. It not only reduced crowd gathering, but also improved the hospital management efficiency.

Internet plus convenience services: to reduce offline gathering and avoid cross infections during COVID-19

During the pandemic, many hospitals provided Internet plus convenience services for the public as specified in Figure 3. Through the publication function of WeChat public account, hospitals launched real-time news and science articles about COVID-19 as part of information campaigns, which prevented rumors and helped the public acquire accurate pandemic knowledge [14, 41]. In addition, many hospital information departments opened time-sharing outpatient appointment services, where the hospital's WeChat public account allowed patients to enter the appointment and registration system according to patients' personal needs. The appointment service helped separate patients' arrival time and reduced the number of people in the doctor's waiting room at one time, containing the spread of the virus [50]. To facilitate communication between intensive care units (ICU) patients and their families, while avoiding staff gathering, some hospitals installed 5G customer premise equipment (CPE) and video calling equipment in ICUs, substituting 5G mobile video for physical visits during COVID-19.

China's Internet plus service pattern also played an important role for overseas Chinese, providing authoritative and scientific knowledge of COVID-19 prevention. The platform was launched on April 7 2020, bringing together 26 well-known Chinese medical institutions and third-party service institutions to provide free Internet consulting services for overseas Chinese. On April 30, a special column aimed at overseas students was launched to provide free health consultation and psychological counseling services. By September 2020, the platform had been visited more than 150 million times, with more than 6 million people providing direct consulting services [46].

Challenges Ahead

According to the 2019 National Health Informatization Survey, significant challenges to China's health informatization remain. Table 2 sets out the challenges to health informatization. First, the number of informatization professionals is small and the distribution of human resources unbalanced. Second, the investment from government and medical institutions is insufficient to support the development of health informatization. An incentive mechanism to encourage social capital to participate in health informatization construction has not been set up in China [3,26]. Third, the IT application rate on health information platforms and in hospitals at all levels remains low. Fourth, the information standards and security systems are incomplete.

Table 2. Challenges on national health informatization.

Factors		Descriptions
Personnel	Quantity	The number of both senior technical personnel and grassroots practical personnel are insufficient.
	Structure	The human resource allocation measured by quality, educational background, professional title and age is unbalanced.
Funds	Financial	Financial support is generally insufficient and shows regional differences.
	Institutional	Low proportion of informatization investment in hospital's annual revenue
	Social	A lack of social capital's participation and government-enterprise cooperation
IT applications	Regional health information platform	Low application rate on municipal and county-level information platforms
	Hospital information system	Low application rate in secondary hospitals and primary hospitals
Systems	Information standard system	A lack of system's interoperability and interconnection, standard management and supervision
	Information security system	A lack of complete and specific systems for standard evaluation and health information security protection

We recommend the following to further promote health informatization in China.

Strengthen top-level design

As identified in Table 2, there is a need to strengthen top-level design. Legal restrictions on some key aspects of national health informatization, such as healthcare big data management, Internet medical information services, privacy protection, information facilities security and network security, need to

be enhanced. The information standard and security systems should be designed in a more unified and specific ways, and information security supervision strengthened [52]. An incentive mechanism should be set up to encourage a diverse range of organizations and institutions, including healthcare institutions, research institutes, universities, associations and enterprises, to participate in the construction of health informatization.

Increase financial investment
As specified in Table 2, finance, taxation and investment arrangements need to be increased to support health informatization, especially from the central government and especially in regions with limited financial resources for health informatization. To address informatization financial constraints, public-private partnerships should be expanded to strengthen the cooperation between the government, business enterprises and various social institutions [26].

Increase qualified personnel
As shown in Table 2, there is an urgent need to increase qualified personnel specializing in health information technologies. An integrated and comprehensive training system should be built to cover junior college, undergraduate, graduate and continuing education students to enlarge the scale of skilled workers. An incentive mechanism should be established to attract experienced professionals and maintain existing personnel in health information departments. To improve the professional level and comprehensive quality of health information personnel, measures should include establishing a national health big data research institute jointly with universities and research institutes, setting up health information majors in colleges and universities, and carrying out continuing education to combine teaching contents with practical work.

Promote IT applications
To address deficits in information platforms and systems identified in Table 2 requires health resource reallocations and promoting advanced technologies to support the new service pattern of Internet plus healthcare. Advanced IT applications, such as cloud computing, big data, mobile internet and artificial intelligence, need to be popularized in grassroots health units. It is necessary to construct more Internet hospitals, building an integrated online and offline medical service model covering pre-diagnosis, in-treatment and post-diagnosis to improve healthcare service efficiency.

Conclusions

As shown by the crucial role in COVID-19 prevention and control, health informatization was 'fit for purpose' in China. Developed over the past decade, health information platforms and health information databases facilitated data sharing between healthcare institutions at all levels, connecting online and offline services. Advanced information technologies, including cloud computing, big data, and artificial intelligence, effectively monitored and forecasted the pandemic's trend that facilitated health authorities' COVID-19 control and prevention ability. The new service pattern of Internet plus healthcare broke through time and space constraints, reduced cross infections, improved medical service quality and efficiency [48], alleviated the shortage of medical resources and met the increasing medical demands during COVID-19. But, China's health informatization was a work in progress, where informatization was incomplete and the uneven regional distribution of health resources persisted. To address the challenges to the health informatization, we recommend the strengthening of top-level design, increasing investment and training, upgrading the health infrastructure and IT applications, and improving Internet plus healthcare services.

Republic of China. In addition, Mian Huang wishes to thank Jacky Cheung. His songs gave her strong spiritual support when she worked under pressure.

References

1. Liang J, Zheng X, Chen Z, et al. The Experience and Challenges of Healthcare-reform-driven Medical Consortia and Regional Health Information Technologies in China: A Longitudinal Study. International Journal of Medical Informatics 2019 Nov;131:103954 [FREE full text] [doi: 10.1016/j.ijmedinf.2019.103954]

2. L. Li, H. Fu. China's health care system reform: Progress and prospects. The International journal of health planning and management 2017 Jul-Sep;32 (3):240-253 [FREE full text] [doi: 10.1002/hpm.2424] [PMID: 28612498]

3. Honghui Yao, Chaohong Zhan, Xinping Sha. Current situation and distribution equality of public health resource in China. Archives of Public Health 2020 Sep;78(1):78-86. [doi: 10.1186/s13690-020-00474-3] [PMID: 32983449]

4. Central Committee and the State Council of the People's Republic of China. Opinions on Deepening the Reform of the Health Care System. URL:http://www.gov.cn/gongbao/content/2009/content_1284372.htm [accessed 2020-10-30]

5. Liu GG, Chen Y, Qin X. Transforming rural health care through information technology: an interventional study in China. Health Policy Plan 2014 Dec;29(8):975–85 [FREE full text] [doi: 10.1093/heapol/czt078] [Medline: 8610614]

6. Melinda Beeuwkes Buntin, Sachin H.Jain, David Blumentha. Health Information Technology: Laying The Infrastructure For National Health Reform. Health Affairs 2010 Jun;29(6):1214-1219 [FREE full text] [doi: 10.1377/hlthaff.2010.0503] [PMID: 20530358]

7. Li C, Xu X, Zhou G, He K, Qi T, Zhang W, Tian F, Zheng Q, Hu J. Implementation of National Health Informatization in China: Survey About the Status Quo. JMIR Med Inform 2019;7(1):e12238 [FREE full text] [doi: 10.2196/12238][Medline: 30789350]

8. Min Chen. Theory and method of regional population health informatization. Bejing: Science Press; 2016. ISBN:9787030486349

9. Ministry of Health of the People's Republic of China. Guiding Opinions on Strengthening Health Informatization Construction. URL:http://www.nhc.gov.cn/zwgk/wtwj/201304/e1b9fd5596ce4a5e8123337552358b38.shtml [accessed 2020-10-30]

10. National Health and Family Planning Commission of the People's Republic of China. Guiding Opinions on Accelerating the Information Construction of Population Health. URL:http://www.nhc.gov.cn/cms-search/xxgk/getManuscriptXxgk.htm?id=ffa4b17e89f6414d9b8a98e5b07f47b7 [accessed 2020-10-30]

11. Hu Jianping, Zhang Lili, Gu Lihua, et al. Health information interoperability and standard system—Practice of China. Health Policy and Technology 2014 Dec;3(4):248-252. [doi: 10.1016/j.hlpt.2014.10.003]

12. National Health and Family Planning Commission of the People's Republic of China. National Population Health Informatization Development Plan for 13th Five-Year Plan. URL:http://www.nhc.gov.cn/guihuaxxs/s10741/201702/ef9ba6fbe2ef46a49c333de32275074f.shtml [accessed 2020-10-30]

13. Fei Zhao, Ping Zhang, Yajun Zhang, Ze Ma. Time to lead the prevention and control of public health emergencies by informatics technologies in an information era. Journal of Biosafety and Biosecurity 2020 Dec;2(2):102-104 [FREE full text] [doi:10.1016/j.jobb.2020.06.001] [PMID: 32954228]

14. Wang CJ, Ng CY, Brook RH. Response to COVID-19 in Taiwan: big data analytics, new

technology, and proactive testing. JAMA 2020 Mar 03. [doi: 10.1001/jama.2020.3151] [Medline: 32125371] [PMID: 32125371]

15. Ye Q, Zhou J, Wu H. Using Information Technology to Manage the COVID-19 Pandemic: Development of a Technical Framework Based on Practical Experience in China. JMIR Med Inform 2020;8(6):e19515. URL: http://medinform.jmir.org/2020/6/e19515/ [doi: 10.2196/19515] [PMID: 32479411]

16. National Health Commission Statistical Information Center of the People's Republic of China. (2019)Survey Report on National Health Informatization. Beijing: People's Medical Publishing House; 2019. ISBN:9787117285278

17. Maenpaa T, Asikainen P, Gissler M, et al. Outcomes Assessment of the Regional Health Information Exchange A Five-year Follow-up Study. Methods Inf Med 2011;50(4):308-318. [doi:10.3414/ME10-01-0048] [PMID: 21336419]

18. Maenpaa T, Suominen Tarja, Asikainen Paula, et al. The outcomes of regional healthcare information systems in health care: A review of the research literature. Int J Med Inform 2009 Nov;78(11):757-771. [doi:10.1016/j.ijmedinf.2009.07.001] [PMID: 19656719]

19. General Office of National Health Commission of the People's Republic of China. Notice of the General Office of the National Health Commission on Informatization Support for Normalized Epidemic Prevention and Control. URL:http://www.gov.cn/zhengce/zhengceku/2020-06/29/content_5522612.htm [accessed 2020-10-30]

20. Sittig, Dean F. Singh Hardeep. COVID-19 and the Need for a National Health Information Technology Infrastructure. JAMA 2020 Jun 16;323(23):2373-2374. [doi:10.1001/jama.2020.7239] [Medline: 7501160]

21. Iakovidis I. Towards personal health record: current situation, obstacles and trends in implementation of electronic healthcare record in Europe. Int J Med Inform 1998;52(1-3):105-115. [doi:10.1016/S1386-5056(98)00129-4] [Medline: 9848407]

22. Meng Qun, Ye Qiang, Hu Jianping, et al. Regional population health informatization construction and development. Beijing: People's Medical Publishing House; 2014. ISBN: 9787117186902

23. National Health Commission of the People's Republic of China. Answers to the Guiding Opinions on Accelerating the Construction of Population Health Informatization. URL: http://www.nhc.gov.cn/guihuaxxs/s10742/201312/2519dea9a4b14318a0736881116275ee.shtml [accessed 2020-10-30]

24. National Health Commission of the People's Republic of China. Opinions on strengthening the construction of the national health information standardization system. URL: http://www.nhc.gov.cn/cms-search/xxgk/getManuscriptXxgk.htm?id=4114443b613546148b275f191da4662b [accessed 2020-10-30]

25. Hu Hongpu, Qin Panpan, Lei Xingyun. The Development Process and Outlook of National Health Informatization in China. Journal of Medical Informatics 2019 Jul;40(7):2-6. [doi: 10.3969/j.issn.1673-6036.2019.07.001]

26. WANG Kun, MAO A-yan, MENG Yue-li, et al. Development history, current situation, problems and strategies of public health system construction in China. Chin J Public Health 2019 Jul;35(7):801-805. [doi:10.11847/zgggws1123311]

27. Health Supervision Center of National Health Commission of the People's Republic of China. Outline of National Health Informatization Development Plan 2003-2010. URL: https://www.jdzx.net.cn/article/4028818a14f4305e0114f43c1b0c0002/2009/3/4028818a163f0d8d01165ca36753005a.html [accessed 2020-10-30]

28. Cresswell Kathrin, Sheikh Aziz, Franklin, Bryony Dean, et al. Theoretical and methodological considerations in evaluating large-scale health information technology change programmes. BMC Health Services Research 2020 May 27;20(1):477 [FREE full text] [doi:10.1186/s12913-

020-05355-7] [PMID: 32460830]

29. McCall, Becky. COVID-19 and artificial intelligence: protecting health-care workers and curbing the spread. Lancet Digit Health 2020 Apr;2(4):E166-E167 [FREE full text] [doi:10.1016/S2589-7500(20)30054-6] [PMID: 32289116]

30. Samra, Halima, Li Alice, Soh Ben. Utilisation of hospital information systems for medical research in Saudi Arabia: A mixed-method exploration of the views of healthcare and IT professionals involved in hospital database management systems. Health Inf Mange J 2020 May;49(2):117-126. [doi:10.1177/1833358319847120] [PMID: 31046465]

31. Lee Junyoung. EMR Management System for Patient Pulse Data. J Med Syst 2012 Oct;36(5):3255-3260. [doi:10.1007/s10916-011-9816-9] [PMID: 22223158]

32. ZHOU Guanghua, XU Xiangdong, HU Jianping. Health Informatization: Development, Characteristics and Prospects. Chinese Journal of Health Informatics and Management 2019 Aug;16(4):384-394. [doi:10.3969/j.issn.1672-5166.2019.04.01]

33. National Health Commission of the People's Republic of China. Answer to Recommendation No. 8113 of the Second Session of the 13th National People's Congress. URL: http://www.nhc.gov.cn/wjw/jiany/202007/082ceb95551b461fafdc85a3f725df5f.shtml [accessed 2020-10-30]

34. National Health Commission of the People's Republic of China. China Health Statistical Yearbook. Beijing: China Union Medical College Press; 2019. ISBN: 9787567913233

35. HAO Xiao-ning, MA Cheng-yu, LU Zhi-ye, et al. The Effects and Problems on the Reform of Primary Health Informatization in China. Health Economics Research 2020 Jul;37(07):3-9. [doi: 10.14055/j.cnki.33-1056/f.2020.07.001]

36. China Hospital Information Management Association. Report on the Situation of Hospital Informatization in China in 2018-2019. URL: https://chima.org.cn/Html/News/Articles/4878.html [accessed 2020-10-30]

37. China Hospital Information Management Association. Research on the fund investment mechanism of regional universal health informatization (III). URL: https://www.chima.org.cn/Html/News/Articles/4845.html [accessed 2020-10-30]

38. Guo Minjiang, Wang Bingqian, Li Juan, et al. International experience of government and social resource cooperation mechanisms in health informatization and its enlightenment. Chinese Health Resources 2017 Jan;20(01):78-82. [doi: 10.13688/j.cnki.chr.2017.16173]

39. XIA Lan-fang, QI Xiao-peng, MENG Yu-jie, et al. Human resources for public health informatization in CDCs at provincial and municipal levels. Chin J Public Health 2013 Sep;29(9):1306-1310. [doi:10.11847/zgggws2013-29-09-18]

40. Hong Zhen, Li Nian, Li Dajiang, et al. Telemedicine during the COVID-19 pandemic: Western China. JMIR 2020 May;22(5):e19577 [FREE full text] [doi: 10.2196/19577]

41. Muhammad Hasnain, Muhammad Fermi Pasha, Imran Ghani. Combined measures to control the COVID-19 pandemic in Wuhan, Hubei, China: A narrative review. Journal of Biosafety and Biosecurity 2020 Nov;2(2):51-57 [FREE full text] [doi:10.1016/j.jobb.2020.10.001]

42. Sjodin Henrik, Johansson Anders F, Brannstrom Ake, et al. COVID-19 healthcare demand and mortality in Sweden in response to non-pharmaceutical mitigation and suppression scenarios. International Journal of Epidemiology 2020 Oct;49(5): 1443-1453 [FREE full text] [doi:10.1093/ije/dyaa121] [Medline: 7802871]

43. Kho Joanna, Gillespie Nicole, Martin-Khan, Melinda. A systematic scoping review of change management practices used for telemedicine service implementations. BMC Health Services Research 2020 Sep;20(1):SI. [doi:10.1186/s12913-020-05657-w] [PMID: 32873295]

44. Xuan Song, Xinyan Liu, Chunting Wang. The role of telemedicine during the COVID-19 epidemic in China—experience from Shandong province. Critical Care 2020 Apr 28;24(1):178 [FREE full text] [doi:10.1186/s13054-020-02884-9] [PMID: 32345359]

45. Liu L, Gu J, Shao F, Liang X, Yue L, Cheng Q, Zhang L. Application and Preliminary Outcomes

of Remote Diagnosis and Treatment During the COVID-19 Outbreak: Retrospective Cohort Study. JMIR Mhealth Uhealth 2020;8(7):e19417.URL:https://mhealth.jmir.org/2020/7/e19417[doi:10.2196/19417]

46. National Health Commission of the People's Republic of China. The regular press conference of National Health Commission on September 9, 2020 introduced the typical cases of the application and development of national health informatization.URL:http://www.nhc.gov.cn/xwzb/webcontroller.do? titleSeq=11343&gecstype=1 [accessed 2020-10-30]

47. National Health Commission of the People's Republic of China. Standardized maturity assessment of national medical and health information interconnection was carried out smoothly. URL:http://www.nhc.gov.cn/mohwsbwstjxxzx/s8553/201907/6c4292d3f95f4dc7b05334e86744 2d42.shtml [accessed 2020-10-30]

48. Farokhzadian Jamileh, Khajouei Reza, Hasman Arie, et al. Nurses' experiences and viewpoints about the benefits of adopting information technology in health care: a qualitative study in Iran. BMC Med Inform Decis 2020 Sep 21;20(1):240 [FREE full text] [doi:10.1186/s12911-020-01260-5] [PMID: 32958042]

49. Han Yangyang, Lie Reidar K, Guo Rui. The Internet Hospital as a Telehealth Model in China: Systematic Search and Content Analysis. Journal of Medical Internet Research 2020 Jul 29;22(7):e17995. [doi:10.2196/17995] [PMID: 32723721]

50. JIANG Kun, FENG Juan, SU Yu-cheng. Prevention and Control Measures of Hospital Informatization from the Perspective of "Fighting Epidemic". Health Economics Research 2020 Oct;37(10):60-62. [doi:10.14055/j.cnki.33-1056/f.2020.10.016]

51. Ina Kenji, Furuta Ryuichi, Kayukawa Satoshi. Medical and dental cooperation using VPN with IPsec in the hospital without dentists. Annals of oncology : official journal of the European Society for Medical Oncology 2018 Oct;29 Suppl 7(vii84). [doi:10.1093/annonc/mdy375.083]

52. Ratwani Raj M, Reider Jacob, Singh Hardeep. A Decade of Health Information Technology Usability Challenges and the Path Forward. JAMA The Journal of the American Medical Association 2019 Feb 26;321(8):743-744. [doi:10.1001/jama.2019.0161] [Medline: 7501160]

Abbreviations

HIT：health information technology
NHC: National Health Commission
AI: artificial intelligence
NHFPC: National Health and Family Planning Commission
HC: health commission
DID: demographic information database
EHRD: electronic health record database
EMRD: electronic medical record database
EHR: electronic health record
EMR: electronic medical record
HIS: Hospital Information System
LIS: Laboratory Information System
PACS: picture archiving and communication systems
VPN: Virtual Private Network
VDI: Virtual Desktop Infrastructure
ICU: intensive care units
CT: Computed Tomography
CPE: customer premise equipment
CHIMA: China Hospital Information Management Association

Supplementary Files

Figures

The 4631-2 framework of health informatization.
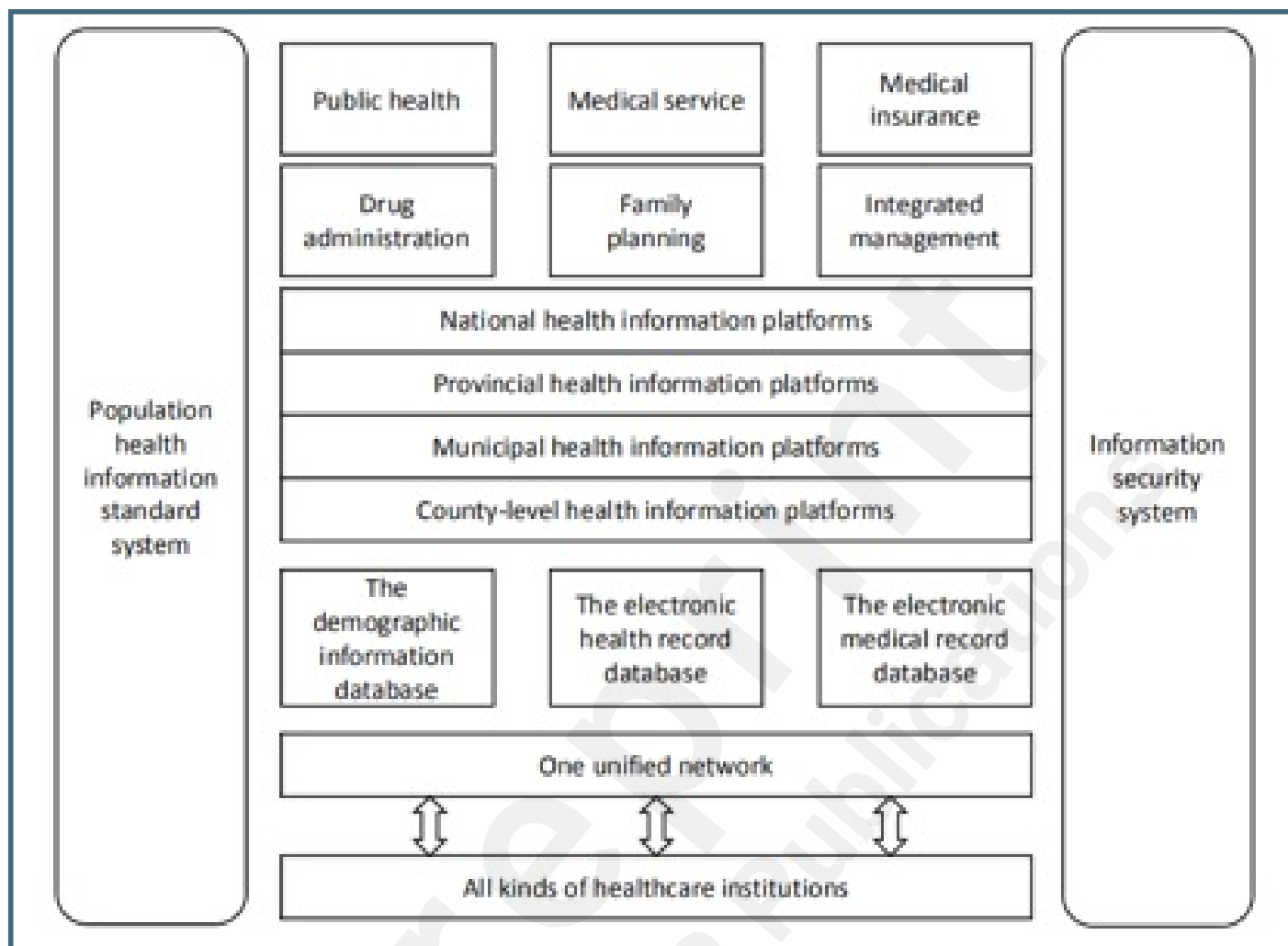
The development history of health informatization in China.

The applications and achievements of Internet plus healthcare in COVID-19.
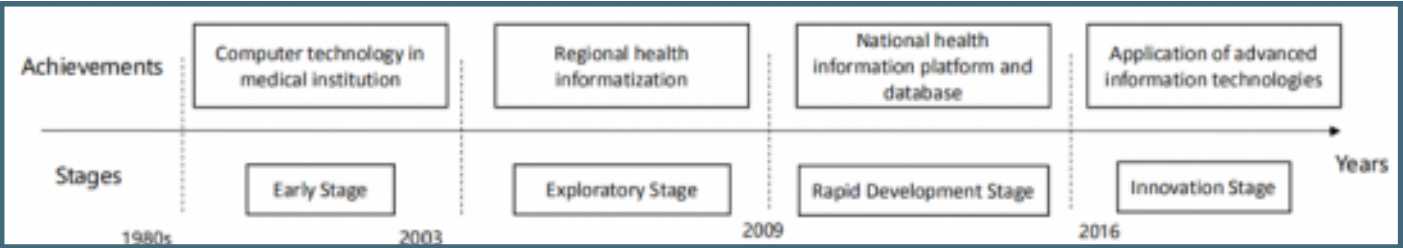

Internet Plus Healthcare Services

Internet hospitals
- Applications: online fever clinics, follow-up visits for common and chronic diseases, psychological counseling services, online payment, etc.
- Achieventments: to meet the demands for basic medical services and alleviate the shortage of medical resources.

Telemedicine
- Applications: remote consultation, remote medical advice and treatment.
- Achieventments: to break regional restrictions and improve treatment.

Internet plus AI diagnosis and treatment
- Applications: AI pre-consultation, self-assessment of personal health conditions, information records, CT scans for COVID-19.
- Achieventments: to improve medical service efficiency.

Internet telecommuting
- Applications: remote office systems, distance learning and teleconferencing.
- Achieventments: to maintain the order and efficiency of medical work.

Internet plus convenience services
- Applications: WeChat public accounts, time-sharing outpatient appointment services, 5G CPE and video calling equipment in ICU.
- Achieventments: to reduce offline gathering and avoid cross infections

COVID-19 prevention and control

An upgrade in China 's healthcare service pattern