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# Construction of Science and Technology Support System for Public Health Emergencies in China

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**Abstract:** China's science and technology support system plays a significant role in the fight against public health emergencies. In this study, we summarized the construction status of China's science and technology support system for emergencies in terms of the (1) layout of scientific research bases and platforms, (2) application of big data technology, (3) science and technology investment in public health, and (4) transformation of scientific and technological achievements. Subsequently, we analyzed the challenges for the construction of a support system in China compared to developed countries that are advanced in medical science and technology. To solve the problems of the weak foundation of basic medical research and lack of key core technologies, we suggest strengthening the synergy of universities, medical institutions, and science and technology enterprises. This will improve China's basic medical research ability and promote the research and development of original pharmaceutical products and diagnostic reagents. Considering the lack of bases and platform facilities in China, we suggest strengthening the construction of national biological resource sample centers and building self-supported data and information-sharing platforms. As for insufficient investment in public health and an imperfect personnel system, we suggest enhancing the leading role of the National Academy of Medical Sciences, increasing the input of public health, and improving personnel evaluation, reserve, and training mechanisms.
**Keywords:** public health emergencies; health; scientific and technological support

## 1 Introduction

Public health emergencies refer to major infectious disease epidemics, mass unexplained diseases, major food and occupational poisoning, and other events that seriously affect public health, which occur suddenly and may cause serious damage to the health of the public [1]. Since the beginning of the new century, there have been frequent outbreaks of new infectious diseases, mainly caused by respiratory viruses, such as severe acute respiratory syndrome (SARS) in 2003, H1N1 influenza A in 2009, Ebola in 2014, and Zika in 2015. The novel coronavirus pneumonia (COVID-19) in late 2019 was defined by the World Health Organization (WHO) as a public health emergency of international concern, representing a severe test of world economic development and social stability and a major test of China's prevention and control system for public health emergencies.

After several major public health emergencies, China has developed its science and technology support system for public health emergencies through the synergy of multiple forces covering clinical treatment, virus traceability, animal model construction, and research and development (R&D) of drugs, vaccines, testing technologies and products. However, China has relatively weak basic R&D of new technologies. In the field of biosafety, for example,

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the localization rate of key and core technical products and medical instruments remains low [2]. The country's drug innovation capacity and industrial development are still far from the advanced international level, with drug R&D equipment and raw materials relying heavily on imports. Pharmaceutical R&D investment is large, high-risk, and long-term, making it difficult for a single R&D institution or enterprise to undertake it [3]. In its efforts to respond to public health emergencies, China also needs to further enhance its capabilities in the R&D of drugs and vaccines, diagnostic reagent production, protective equipment stockpiling, and medical equipment supplies [4]. Compared to the United States of America (USA), China has evident gaps and shortcomings in developing research infrastructure, such as data resource centers and biosafety laboratories [5]. To strengthen scientific and technological support for the public health system and enhance its ability to address public health security, China needs to focus on meeting the demand for scientific and technological talents in public health and explore and improve the mechanism for training talents. There is a need to strengthen basic research in medical sciences, explore research on disease etiology, pathogenesis, diagnosis, and treatment mechanisms, and facilitate original innovation [6]. It is necessary to gain insight into the response capabilities of public health emergencies, identify key aspects from basic biological experimental techniques, protective facilities of high biosafety level laboratories, and important medical treatment and testing equipment, and determine the main direction of research. The development of rapid response technology platforms and biological resource information-sharing platforms should also be emphasized [7].

Overall, existing studies in China have focused on the role of science and technology support in preventing and controlling the COVID-19 pandemic. The analysis perspective lies in establishing a public health system for emergency management, improving early warning mechanisms for epidemic prevention and control, and enhancing biosafety governance capacity. However, there is a shortage of comprehensive analyses and systematic research on science and technology support systems for public health emergencies. However, some research conclusions lack solid theoretical data. This study highlights the supporting role of China's science and technology innovation system and capacity in public health emergencies and analyzes the shortcomings and gaps in science and technology capacity building. It also puts forward targeted suggestions for key issues, such as weak basic medical research, lack of key and core technologies, inadequate platform facilities, insufficient overall research investment, and imperfect talent systems based on useful international experiences.

## 2 Current development of China's science and technology support system for public health emergencies

### 2.1 Improvements in research bases and platforms

As of August 2020, China has built 986 biotech bases and platforms, including 74 national key laboratories (five developed by multiple institutes across provinces) in the biomedical field, 31 national key laboratories co-built by provinces and ministries, 31 national key laboratories built mainly by enterprises, and 50 national clinical medical research centers built mainly by hospitals [8]. The country has made arrangements for common and frequently occurring diseases, major chronic diseases, prevention, control, and treatment of infectious diseases, new drug research, and traditional Chinese medicine. The country has built Asia's largest drug compound library and optimized national sharing platforms for science and technology resources in the health sector, including the National Human Disease Animal Model Resource Center.

Amid the COVID-19 pandemic, China relied on the Detection Technology Platform for Emergency Response to Major Infectious Diseases and Infectious Disease Surveillance Technology Platform supported by the project on infectious diseases to confirm the novel coronavirus (SARS-CoV-2) as the pathogen of this unexplained pneumonia within five days, isolated the SARS-CoV-2 strain, and spliced the full genome sequence of the virus, which was highly applauded by WHO as "screening the pathogen in record short time." The country is the first in the world to establish mouse, Rhesus macaque and Cynomolgus macaque models to address the COVID-19 pandemic based on the National Human Disease Animal Model Resource Center, which has been designated as the national platform for vaccine and drug evaluation. Seven of the first eight vaccines were evaluated, and hundreds of drugs were screened and evaluated. This provided strong support for the development of vaccines and drugs.

### 2.2 Big data technology for epidemic monitoring and scientific research

To prevent, control, and monitor the COVID-19 pandemic, a special big data task force was set up under the State Council's joint prevention and control mechanism for the COVID-19 pandemic. The scientific research group established an information technology task force to conduct virus tracing, a transmission chain analysis, epidemic surveillance, and a risk assessment based on the number of confirmed patients, suspected cases, close contacts,

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foreign inflow population, geospatial information, and remote sensing monitoring data offered by multiple ministries [9]. In unifying health information codes across the country, the national integrated government service platform launched the Health Code for Epidemic Control", which has been applied nearly 900 million times and used over 40 billion times [10].

In promoting scientific research and outcome sharing, the Ministry of Science and Technology, National Health Commission, and Chinese Medical Association established a specialized communication platform for research outcomes of COVID-19 prevention and control and integrated and shared research results, papers, experimental data, clinical cases, and important progress of COVID-19 research projects [11]. The National Population Health Data Center released the "novel coronavirus pneumonia terminology" and built the "novel coronavirus pneumonia data sharing system" to provide scientific data, research literature, outbreak reports, epidemic prevention guidelines, protection knowledge, and other information services. To facilitate the sharing and application of SARS-CoV-2 genomic data, the China National Center for Bioinformation (CNCB) and National Genomics Data Center (NGDC) of China developed and maintained the 2019 Novel Coronavirus Information Repository (2019nCoVR), integrating publicly released information, such as SARS-CoV-2 nucleotide and protein sequence data from the Global Initiative on Sharing All Influenza Data, the US National Center for Biotechnology Information (NCBI), Shenzhen (National) Gene Bank, the National Microbiology Data Center (NMDC) of China, CNCB, NGDC, and other institutions. NMDC established a global coronavirus data sharing and analysis system and built the National Science and Technology Resource Service System for Novel Coronaviruses together with the National Pathogen Resource Center of China and other institutes, which strongly supported the collection, sharing, and analysis of coronavirus data in China and beyond [8].

### 2.3 Growing investment in public health science and technology

China's research on public health emergencies is primarily funded by the National Natural Science Foundation of China (NSFC), and by the National Major Science and Technology Project and the National Key Research and Development Program launched by China's Ministry of Science and Technology. In 2009, the NSFC launched a major research program on the "management of unconventional emergencies," which funded 120-plus projects with a total funding of 120 million CNY [12]. By 2020, the national science and technology key project of "major new drug creation" had supported over 3000 subjects with a total investment of 23.3 billion CNY by the central government of China [13]. As of 2018, 2.8 billion CNY had been invested in the "prevention and control of major infectious diseases such as acquired immune deficiency syndrome and viral hepatitis" to support 170 projects related to the prevention and control of sudden acute infectious diseases [14]. In 2020, the NSFC funded 44 public health projects, with a total funding of 17.95 million CNY. It released guidelines and long-term plans for SARS-CoV-2 projects (Table 1) to strengthen research and response efforts in the direction of COVID-19 [15–18].

**Table 1** Status of COVID-19-related guidelines released by NSFC.

| Release time | Title of guideline | Duration of funding | Funding intensity | Number of funded projects |
|---|---|---|---|---|
| January 2020 | Basic Research on the Traceability, Pathogenesis, and Control of Novel Coronavirus (2019-nCoV) | 2 years | Direct funding intensity is about 1.5 million CNY per project | ~20 |
| February 2020 | Response, Governance, and Impact of Public Health Emergencies such as the COVID-19 Pandemic | 1 year | Direct funding is 10 million CNY, and direct funding intensity ranges from about RMB500,000 to RMB800,000 per project | 20 |
| May 2020 | Guidelines for the China-Germany Collaborative Research Project for Emergency Response to Novel Coronavirus | 1 year | Total funding from both China and Germany does not exceed 1.5 million CNY (or equivalent in Euros) per project | ≤ 20 |
| September 2020 | Guidelines on the 2020 Collaborative Research Project of Novel Coronavirus Pneumonia (COVID-19) between National Natural Science Foundation of China and New Zealand Health Research Council | 2 years | Direct funding intensity for the approved projects does not exceed 1.5 million CNY per project on the Chinese side and 350,000 NZD per project on the New Zealand side. | ≤ 3 |

*Note*: Data are from NSFC's website.

### 2.4 Application of research outcomes

China has taken the initiative to respond to acute infectious diseases and chronic major diseases; meet public health, health promotion, and other needs; and facilitate the application of scientific and technological achievements. Nucleic acid screening reagents for human immunodeficiency virus (HIV) are domestically produced, shortening the window period for HIV testing from 28 to 11 days. Nucleic acid screening in blood banks became a national policy in 2016, covering the entire country. Remarkable advances have been made in the study of novel vaccines, immunotherapies, and other cutting-edge technologies. As of July 2019, 139 national science and technology major projects for "major new drug creation" had been awarded new drug certificates, of which 44 are Class 1 new drugs [19]. As of 2018, over 280 generic drugs had been registered in Europe and the USA, 29 drugs supported by special projects had been approved in developed countries of Europe and the USA, and 23 formulations and four vaccine products had been pre-qualified by the WHO [20]. Based on the Cortellis database and the National Medical Products Administration website data, 43 drugs and vaccine products and 58 COVID-19 testing devices and diagnostic reagents developed by China were on the market in 2020.

## 3 Gaps and shortcomings in developing China's science and technology support system for public health emergencies

### 3.1 The original innovation capacity of public health needs to be enhanced with science and technology efforts

3.1.1 R&D capabilities of drugs and vaccines

China's biopharmaceutical enterprises and research institutes have enhanced their R&D capabilities regarding drugs and vaccines for public health emergencies. However, there is still a gap between China and developed countries in Europe and the USA in basic innovation, pilot tests, industrialization, and the total number of products under development. According to the Cortellis database, by September 2021, the number of drugs and vaccines related to major infectious diseases (including plague, cholera, SARS, influenza, Zika, Ebola, poliovirus infection, and COVID-19) in the USA, EU, and China were 1102, 517, and 437, respectively. Of these, the number of COVID-19 infection-related drugs and vaccines developed on the three sides were 739, 365, and 248, respectively (Fig. 1). There are huge funding needs and long R&D cycles for new drug and vaccine development. For example, R&D funding for a single antibody drug can be up to 200 million USD and even 500 million USD in the case of difficult pharmaceutical development. It is more difficult for a research institute or biopharmaceutical company to undertake this task on its own [3].

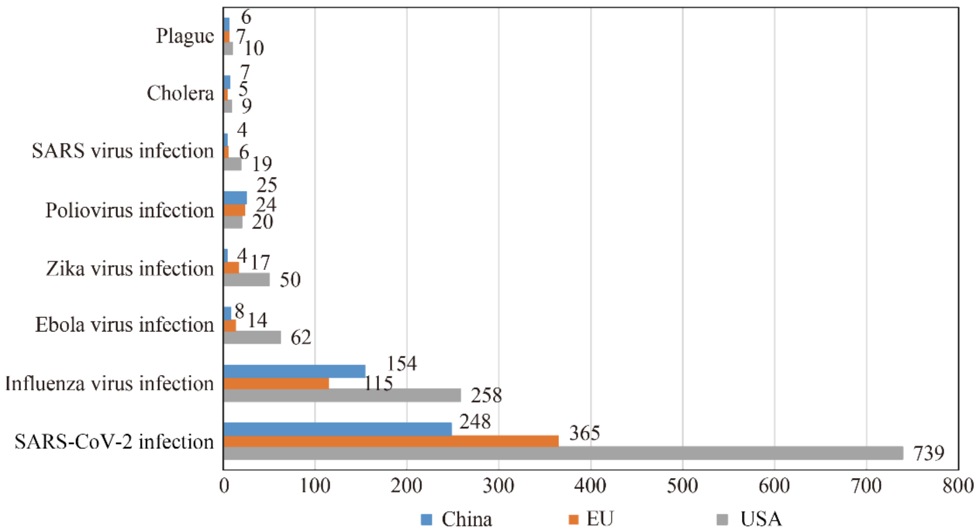


**Fig. 1.** Number of drugs and vaccines developed by the USA, EU and China (based on the Cortellis database, as of September 2021).

3.1.2 R&D capability of testing devices and diagnostic reagents

High-performance detection products, medical instruments, and other prevention and control products provide important scientific and technological support in responding to public health emergencies. However, testing devices and diagnostic reagents related to China's public health are still more dependent on imports, and innovation of

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principle is particularly insufficient. Based on the website data of the National Medical Products Administration and the US Food and Drug Administration, there were 70 products developed by China in the past five years for testing devices and pathogenic diagnostic reagents for major infectious diseases (Fig. 2, including COVID-19, influenza, and Zika), and the corresponding number in the USA was 291. In 2020, China had 58 COVID-19-related testing devices and diagnostic reagents on the market, while the USA had 274. It can be seen that the R&D investment and industrial scale of China's testing devices and diagnostic reagents still need to be further expanded. Cross-disciplinary fields involving the R&D of antiviral drugs, vaccines, antibodies, instruments, and equipment still need to be improved. Prospective, practical, and exploratory research on unknown infectious diseases needs to be strengthened.

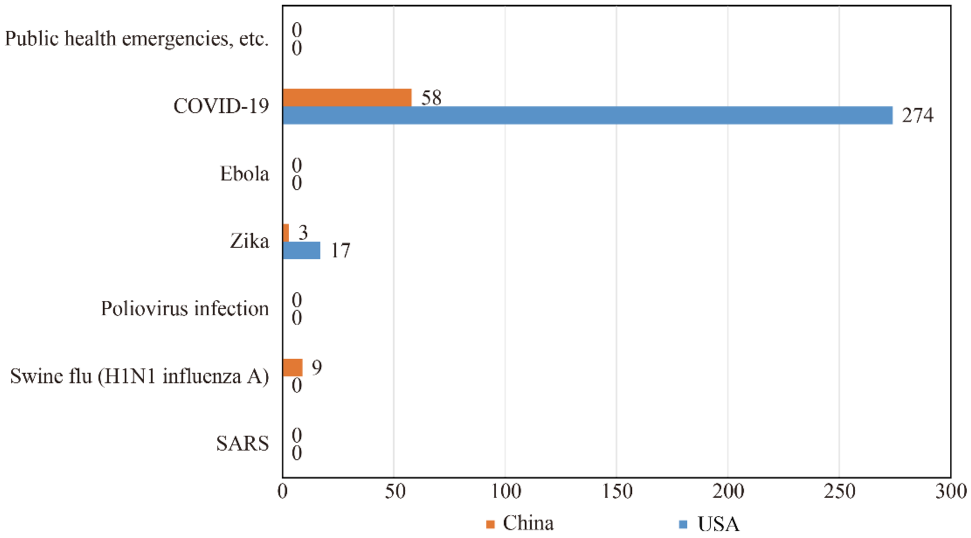


**Fig. 2.** Number of testing devices and diagnostic reagents involved in public health emergencies in China and the USA (2016–2020).

### 3.2 Science and technology resource bases and platforms for public health need to be strengthened

3.2.1 Development of public health resource platform

China needs to improve its national laboratory system for public health. The country needs to strengthen its national platforms for the storage, management, and sharing of biomedical data and national biological sample resource platforms for bacteria and virus species, cell strains, experimental animals, literature resources, and population cohorts [21]. Due to the high international dependence on biomedical technology and resource sharing, there is still a chance of being constrained by others. The convergence standards and sharing mechanisms of research resources, such as databases, sample banks, and biorepositories, need to be improved. The huge resources have not yet been transformed into science and technology outputs for public health [21].

3.2.2 Development of high biosafety level labs

China has lacked the sound deployment of high biosafety level laboratories, with a number lower than that of developed countries, such as the USA. By 2020, there were 81 biosafety level (BSL) three laboratories that have passed the construction review of the Ministry of Science and Technology of China [5], but only a dozen of them are actually put into use. Geographically, they are concentrated in Beijing, Guangzhou, Shanghai, Wuhan, and other cities. From an industry perspective, they are mainly distributed in customs, inspection and quarantine, and centers for disease control. Almost all high-level medical schools and universities in the USA are equipped with BSL-3 laboratories. In 2011, the USA built 1495 BSL-3 laboratories. By December 2017, 54 BSL-4 laboratories were built and under construction in 23 countries worldwide. Of these, there are 12, 5, and 3 in the USA, the United Kingdom (UK), and China, respectively [22].

### 3.3 Science and technology support system for public health emergencies needs to be bettered

3.3.1 Overall investment in science and technology research on public health

China's public health research funding primarily comes from the NSFC that focuses on basic research, and the National Key Research and Development Program and National Science and Technology Major Project that are established on a medical basis. The lack of dedicated medical science funds has restricted the ability to support science and technology in public health emergencies in China. China still has a gap in the total amount of public health research funding compared to developed countries such as the USA. In fiscal year 2018, the total funding in life sciences under the National Institutes of Health (NIH) umbrella amounted to 36.3 billion USD [23], and approximately 18.1 billion USD was invested in public health based on NIH RePORTER. Based on the NSFC funding data in 2018, the central government of China invested approximately 13 billion CNY in life sciences research, and government-owned research institutes spent approximately 269.17 billion CNY on research [24].

3.3.2 Ability of national-level institutes to coordinate research on public health emergencies

Countries at the forefront of medical science and technology rely on national medical research institutes, such as the NIH, Institut National de la Sante et de la Recherche Medicale (INSERM), UK Medical Research Council (MRC), and UK National Institute for Health Research, to coordinate and allocate national funding in medicine and health and lead national medical research covering science and technology studies on public health emergencies. By contrast, China's national medical research institutes need to bring their leading role into full play.

3.3.3 Public health professionals

The pool of professional talent to build China's public health system is insufficient. Among the national health workforce, the share of health workers in disease control institutions was 2.53% in 2009 and 1.53% in 2020, indicating a continuous downward trend [25]. Meanwhile, there is a relative lack of professionals engaged in the R&D of vaccines, antiviral drugs, testing products, and medical instruments in China, especially top-notch talents with multidisciplinary knowledge, epidemic theory of infectious diseases, insightful international vision, and rich experiences.

## 4 Suggestions on strengthening China's science and technology support system for public health emergencies

### 4.1 Conducting key and core technology research to play the role of science and technology support

China must strengthen its capacity for basic medical research. China needs to utilize artificial intelligence (AI), big data, and other new technologies to conduct research on virus traceability, transmission pathways, pathogenesis, and hazard lethality of new public health emergencies to meet clinical application demands. It is necessary to establish an international-leading combined pathogen screening technology system and early warning traceability technology system to improve the overall response capability of public health emergencies.

China needs to enhance the R&D capability and responsiveness of its original pharmaceutical products and diagnostic devices. The country needs to coordinate the development of drugs and vaccine products for public health emergencies at the national strategic level, expedite clinical trials and market use of vaccines, and increase the total number of drug and vaccine products being developed and marketed. It is necessary to strengthen the R&D capability of high-end medical devices and testing reagents; develop common key technologies and technical standard systems; and improve the localization of key raw materials, high-end medical equipment, and testing reagents. A stockpiling system for emergency drugs, vaccines, and medical instruments should be built, and an authorized management system should be established for the emergency use of therapeutic drugs, vaccine products, and medical devices.

China needs to strengthen close cooperation among universities, medical institutions, and science and technology enterprises and establish a cooperation system that focuses on major research tasks among universities, research institutes, and medical institutions. To stimulate the innovation vitality of biotech enterprises, it is suggested that government departments provide policy support, broaden their financing channels, and establish a mechanism to industrialize the achievements of basic medical research [26].

### 4.2 Improving science and technology resource bases and platforms for public health to enhance independent science and technology support capacity

China needs to double its efforts to develop biological sample resource centers. The country needs to strengthen the development of national biological sample resource centers for bacteria and virus species, cell strains, medicinal resources, laboratory animals, biological samples, and human genetic resources; establish large cohort projects and rare disease patient repositories; improve standards and sharing mechanisms for various resource platforms; and promote the rational use of limited resources.

China must build a high-quality data management and information-sharing platform with self-supporting capabilities. Drawing on the successful operational experiences of the NCBI, US National Library of Medicine, and European Bioinformatics Institute, China needs to build an international-leading national medical library, a localized

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global biomedical literature retrieval system, and a national clinical data center [21] to promote high-quality sharing of information on biomedicine, library materials, research literature, medical patents, and clinical trial data [7].

China needs to improve the deployment of high-BSL and national laboratories. According to the regional population density, pathogen detection, and research needs, it is necessary to increase the fixed BSL-3 and 4 laboratories according to local conditions, which are to be supplemented by small mobile BSL-3 and 4 laboratories to meet the needs of responding to public health emergencies. It is necessary to strengthen the development of national key laboratories for public health and give full play to the industry-leading role of national medical centers and national clinical medical research centers.

### 4.3 Improving public health security system to build up comprehensive capacity to respond to public health emergencies

China needs to pool more scientists and engineers who specialize in public health. It is necessary to improve the evaluation system of public health and clinical medical talent and break the assessment methods in which only papers and impact factors matter. Scientific collaboration must be motivated by the need to identify the lead and corresponding authors. China needs to improve the system of talent selection, recruitment, training, reserve, and incentive and attract high-caliber interdisciplinary public health talents with international vision. Therefore, it is necessary to establish national and local emergency response teams and conduct regular emergency prevention and control drills.

China needs to give full play to the Chinese Academy of Medical Sciences' role as coordinator and leader. The country needs to strengthen the development of national labs for medicine and health, establish a real national academy of medical sciences [21], draw on the experiences of NIH, INSERM, MRC, and other institutions, and fully play the role of coordinating medical science and technology innovation resources and leading medical science and technology innovation. It needs to focus on the life and health of the population and carry out continuous scientific research to implement major strategies for medical science and technology innovation and meet the needs of prevention and control of public health emergencies. It is necessary to integrate advantageous science and technology resources and research forces; coordinate the arrangements of scientific research in population health and biosafety; and strengthen basic, cutting-edge, and non-profit research on the innovation of health science and technology.

China must increase its investment in science and technology for public health. It is suggested that a special medical research fund be established, in addition to the existing five major science and technology programs (special projects and funds), to independently manage science and technology resources in health care [21]. China needs to steadily sustain basic research in life sciences and medical and healthcare key and core technologies and strengthen strategic technological forces in epidemics, disease prevention and control, and public health as soon as possible.

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