Frontier Interdisciplinary Strategy

Research on Surveillance and Early Warning of Emerging Infectious Diseases

Research on Surveillance and Early Warning of Emerging Infectious Diseases Research Team

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Report Writing Group

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Abstract

Since the turn of the new century, emerging and re-emerging infectious diseases have continuously posed severe threats to global human security, with a high likelihood of future pandemics. The World Health Organization (WHO) has explicitly warned of the potential outbreak of "Disease X"—a hypothetical pathogen with pandemic potential. Establishing an efficient and sensitive surveillance and early warning system is not only essential for effectively addressing such challenges but also a critical measure to advance cross-disciplinary research in related fields, support socioeconomic development, and safeguard national biosecurity. This endeavor carries profound strategic significance.

Currently, China's surveillance and early warning system faces challenges such as delayed detection of new infectious disease threats, inaccurate early warnings, and fragmented information integration. To tackle scientific issues like the timeliness of abnormal signal detection, the scientific validity of early warning decisions, and the rationality of risk assessments, disruptive technological breakthroughs are required in integrating artificial intelligence (AI), big data analytics, and high-throughput pathogen detection into the surveillance framework.

It is proposed that China should adopt a development pathway characterized by independent control, open cooperation, and intelligent innovation. By fully leveraging its institutional advantages and promoting synergies across military-civil integration, medical-preventive coordination, and interdisciplinary resource integration, China can build a nationwide surveillance and early warning network that ensures full territorial coverage and rapid responsive capabilities.

Content

Chapter 1: Surveillance and Early Warning of Emerging Infectious Diseases as a National Biosecurity Strategy

The prevention and control of emerging infectious diseases (EIDs) are crucial to public health, economic development, social stability and national security. Surveillance and early warning, as the primary link in the prevention system, are of self-evident importance.

Section 1.1: The cutting-edge nature of EID surveillance and early warning research

1. Surveillance and early warning: The first link in the EID prevention and control chain

The entire chain of EID prevention and control includes prediction, surveillance, early warning, diagnosis, research, prevention, treatment, rehabilitation, and evaluation. Surveillance and early warning constitute the first line of defense and represent the forefront of cutting-edge science and technology. For example, since October 2023, many regions in China, especially children's hospitals, have faced a complex epidemic of respiratory infectious diseases primarily involving Mycoplasma pneumoniae, influenza virus, respiratory syncytial virus (RSV), and adenovirus. The surge in patient numbers has created unprecedented pressure. A key problem identified was the insufficient role of early surveillance and inadequate preparedness in early warning studies and judgments.

2. Complex Sources of Emerging Pathogens Pose Severe Challenges to Surveillance and Early Warning

Changes in the ecological environment and climate have profoundly affected pathogen epidemic characteristics and increased the risk of cross-species transmission of unknown pathogens. Population growth, socialization, and economic globalization accelerate the spread of infectious diseases. As the scope of human activities expands, the possibility of introducing polar microorganisms and mutant pathogens from outer space increases. As EIDs become more harmful and uncertain, prevention and control pressure intensifies, making proactive responses increasingly vital. This necessitates more timely and accurate surveillance and early warning.

3. Surveillance and Early Warning: Becoming the Forefront and Core of International Biotechnology Competition

Advancements in synthetic biology technology and the deep integration of artificial intelligence (AI) in biosecurity have increased the risk associated with artificially modified organisms, further elevating the possibility of new infectious diseases and escalating the difficulty of surveillance and early warning. Therefore, it is necessary to establish a regular surveillance, situational awareness, and intelligent early warning platform for the man-made or accidental spread of new infectious diseases to address potential threats. The shift in EID prevention and control strategy from passive response to active defense has become inevitable and represents a new strategic high ground in international biotechnology competition.

Section 1.2: EID Surveillance and Early Warning Research Driving Rapid Development in Biosecurity

A new round of scientific and technological revolution and industrial transformation has given rise to new business formats and models in biotechnology. Research on EID surveillance and early warning also plays a key role in promoting the development of the biosecurity field.

1. Promoting Theoretical and Technological Innovation

Surveillance and early warning hold a primary position in the EID prevention and control system. In-depth research and development will comprehensively optimize prevention and control strategies, playing a significant role in driving system construction. It can drive theoretical and technological innovation in microscopic pathogen research, transmission dynamics, and macro-strategies, while also providing a realistic need for early, precise prevention and control, effective containment, and risk reduction before an outbreak occurs.

2. Promoting Interdisciplinary and Collaborative Innovation

EID surveillance and early warning involve multiple disciplines, such as epidemiology, infectious diseases, microbiology, molecular biology, mathematics, statistics, and genetics, as well as technical support from big data, the Internet of Things (IoT), cloud computing, and artificial intelligence (AI). The cross-integration of these disciplines not only promotes development and innovation within their respective fields but also lays a solid foundation for the emergence of new cutting-edge interdisciplinary fields and even systematic collaborative innovation.

3. Promoting the Development of Industrial Science and Technology

Research on EID surveillance and early warning leads cutting-edge biotechnology innovation, promotes the efficient transformation and application of bio-manufacturing technological achievements, drives the deep integration of industry, academia, research, and application, and achieves seamless connection between basic research, applied research, and technological development. By fostering close cooperation between scientific research and industry, we can understand industrial needs, integrate technology with industry, and promote the transformation of technology into new productive forces. With the continuous deepening of surveillance and early warning research, it is expected to establish a more complete and efficient bio-manufacturing industry chain, providing solid support for the innovation and upgrading of the biotechnology industry.

4. Promoting Talent Training and Team Building

EID surveillance and early warning encompass multiple types and multi-dimensional work, such as infectious disease surveillance, syndrome surveillance, and pathogen surveillance, involving the disease control system, medical institutions, scientific research units, bio-pharmaceutical companies, and even public security and transportation departments. Given its wide coverage, large workload, and strong collaborative nature, it will significantly promote talent development in related fields such as epidemiology, infectious diseases, etiology, and digital biology, and foster a large number of high-level cross-disciplinary teams.

Section 1.3: The Practical Value of EID Surveillance and Early Warning Research in Meeting National Strategic Needs

1. Meeting the Practical Needs of the National Biosecurity Strategy

As the field of biosecurity continues to expand, the nature and scope of biological threats are undergoing profound changes. From accidental risks to persistent threats, from single sources to diversification, and from local areas to global regions, the impact scope of biological emergencies continues to widen, relating not only to public health but also to national security and strategic interests. Historical instances of biological warfare and bioterrorism attacks, as well as potential future "Pathogen X" or highly pathogenic engineered pathogens, all pose major biosecurity challenges. Therefore, strengthening EID surveillance and early warning research is indispensable and of practical significance for ensuring national, regional, and even global biosecurity.

2. Meeting the Urgent Needs of the National Strategy of Scientific and Technological Innovation

The field of EID surveillance and early warning has become a frontier in global scientific and technological competition, characterized by its cutting-edge, breakthrough, and potentially disruptive nature. Western developed countries, led by the United States, continue to increase investment in science and technology, accelerate global deployment strategies, and strive to safeguard national security through technological breakthroughs while ensuring their leading position in global science and technology. China must strengthen scientific and technological innovation in EID surveillance and early warning to enhance its status on the international scientific and technological stage. This is crucial not only for national biosecurity but also for China's overall scientific and technological innovation capabilities and international competitiveness.

3. Integrating into the National Strategic Mission of Military-Civilian Integration

Infectious diseases pose a major threat to biosecurity, and their prevention and control constitute an important part of national defense biosecurity operations. The characteristic of infectious diseases spreading rapidly without distinguishing between military and civilian populations necessitates comprehensive participation in their prevention and control. Surveillance and early warning research holds unique needs and advantages in strengthening the military through science and technology and advancing military-civilian integration. Integrated military-civilian surveillance and early warning capabilities are also an inevitable requirement for building an integrated Healthy China strategic system and capabilities.

4. Meeting the Long-Term National Strategic Needs of Building a Community with a Shared Future for Mankind

EIDs have seriously affected global security, posed severe challenges, and provided important opportunities for building a community with a shared future for human health. Through in-depth cooperation with the WHO and countries along the "Belt and Road" in areas such as infectious disease emergency response, prediction, surveillance, and early warning, China has contributed Chinese wisdom and solutions to building a prevention and control science and technology system with Chinese characteristics. This helps expand China's international influence and meets the strategic needs of demonstrating China's responsibility as a major country and realizing the important concept of a community with a shared future for mankind.

Section 1.4: The Value of EID Surveillance and Early Warning Research in Promoting National Economic and Social Development

1. Significant Value for Constructing an Industrial System for the Entire Biotechnology Industry Chain

Establishing a complete biotechnology industry chain and supply chain is crucial for EID prevention and control. Achieving self-reliance and self-strengthening in science and technology, especially in key theories, technologies, and products, is the cornerstone of ensuring industrial chain security. Addressing China's lack of independent capabilities in this field, we will focus on weak links and core issues through extending, supplementing, and strengthening the chain. This involves innovative drug R&D, vaccine development, diagnostic reagents, AI, super-computing, mathematical models, electronic technology, and other fields intersecting with biotechnology. Promoting close cooperation between upstream, midstream, and downstream sectors will improve the bio-pharmaceutical industry system and foster R&D and innovation in the application of foundational technologies.

2. Significant Value for Integrating Social Resources and Optimizing Resource Allocation

Surveillance and early warning research not only focuses on human infectious diseases but also involves surveillance of animal and environmental pathogens, which is highly significant for protecting animals, preventing animal infectious diseases, and ensuring ecological environment safety. This research can also effectively address ecological and environmental challenges by implementing response strategies, such as strengthening domestic waste management, promoting environmentally friendly disinfection measures, improving the environmental sustainability of vaccine production and distribution, and enhancing environmental monitoring and governance. Simultaneously, research in this field promotes the cultivation and team building of relevant professional talents, provides professional positions for industrial development, and thus contributes to the integration and optimal allocation of social human resources.

Chapter 2: Key Scientific Issues and Core Technical Tasks for Monitoring and Early Warning of Emerging Infectious Diseases

Section 2.1: Main Problems in the Field of EID Surveillance and Early Warning

Numerous problems persist in the field of EID surveillance and early warning. Summarized, they are mainly reflected in: "detection not early enough, early warning not accurate enough, and data resources not integrated enough".

1. Weak Technical Capability of the Surveillance System, Detection Not Early Enough

Health emergencies are sudden and social in nature. Early surveillance, scientific risk assessment, and early warning suggestions are vital preliminary work. Although China has established online direct reporting, influenza surveillance, and laboratory monitoring platforms for infectious diseases, which played significant roles in COVID-19 prevention and control, higher standards and realistic needs for preventing "Disease X" reveal major shortcomings of "detection not early enough". Specifically, key problems include: generally weak technical capability in surveillance and early warning, unsystematic surveillance network technology, insufficiently fast detection and screening of unknown pathogens, and prediction and early warning models unsuitable for new EIDs.

2. Low Automation Level of the Warning System, Early Warning Not Accurate Enough

The difficulty in controlling unknown EIDs lies in integrating complex early surveillance information, conducting discriminatory analysis, combining it with practical judgment, and making decisions most beneficial to epidemic prevention and control and socioeconomic impact. The early warning system needs to eliminate interference and provide sufficient basis for decision-makers. Currently, China's early warning system still suffers from low automation and a clear problem of "too many human interference factors, and warning support not accurate enough". This includes: underdeveloped automatic integration technology for clue information in the surveillance and early warning system; strong dependence on foreign sources for basic technologies, fundamental data, etc.; and largely passive predictions, significantly reducing early warning accuracy and limiting the scientific nature of decision-making.

3. Data Sources Scattered and Complicated, Utilization Efficiency Low

Achieving effective early warning for EIDs requires accurate, highly identifiable, and comparable data information as a prerequisite. This necessitates unified data formats, clear classification, and standardized sources. Reviewing COVID-19 prevention and control, the main reasons for initial chaos included: multiple information sources, complex types, varying formats, and low standardization, intelligence, and integration, making it difficult to utilize this information scientifically for decision support. There is an urgent need to enhance the multi-dimensional proactive and intelligent integration of data information, improve the utilization of information across multiple time periods, channels, and scenarios, and enable surveillance and early warning systems to leap from digital to intelligent modes. This could even allow them to become "wise decision-makers", avoiding human biases in decision-making.

Section 2.2: Key Scientific Issues in Cutting-Edge and Cross-Cutting Fields

Predicting outbreaks of major infectious diseases is like exploring the future in the fog and has always been a global challenge. Cutting-edge technologies such as big data, cloud computing, and AI have brought revolutionary progress to epidemic perception and early warning, but many scientific problems remain. These include, but are not limited to:

1. How to Improve the Timeliness of Abnormal Signal Detection

Humanity has often been passive in responding to EIDs historically. Epidemics have forced research, which is clearly insufficiently timely. The reason is that traditional surveillance methods rely on clinical symptoms, while the core of surveillance and early warning lies in early prevention. Clinical symptoms in a case often appear only after the pathogen has already spread within the population, especially for emerging respiratory infectious diseases with potentially non-specific symptoms. Case surveillance based on clinical symptoms cannot achieve early detection of abnormal signals. Therefore, current challenges include: How to effectively sample from nature or hosts before the pathogen infects humans to capture risk information? How to combine AI and high-throughput experimental technology to quickly identify potential risks? How to integrate multi-source data (e.g., medical, environmental, transportation, population, big data, public sentiment) to discover unknown infectious disease risks through active surveillance? And how to evaluate the timeliness of this active surveillance?

2. How to Achieve the Scientific Nature of Early Warning Decision-Making

To improve the accuracy of early warning of emerging infectious diseases, multidisciplinary interaction is the key. To integrate multi-source monitoring information, identify abnormal signals from massive data and determine early warning levels to avoid false alarms or omissions, it is necessary to develop corresponding technologies and establish effective systems and mechanisms. This involves scientific issues such as data layering, extraction, integration, pattern recognition, interference elimination, cross-fusion and multi-point triggering, especially how to effectively capture and amplify low-frequency signals, identify false negative/positive signals and noise, and how to ensure sensitivity while enhancing the robustness and universality of the system.

3. How to Improve the Rationality of EID Early Warning Assessment Through Multidisciplinary Research

Future EID surveillance and early warning should integrate the theories and technologies of surveillance, early warning, and multi-modal simulation. This requires utilizing cutting-edge cross-cutting technologies to integrate multi-source surveillance data and multi-source geographic information systems to achieve real-time dynamic display, analysis, and evaluation of the overall epidemic situation, and to assess the timeliness and scientificity of EID early warning information in real-time. Developing distributed data analysis and numerical calculation methods, integrating the dynamics of population immune levels and the spatio-temporal effects of epidemic scale, and using scientific calculations to analyze and judge epidemic spread in real-time are essential. The surveillance and early warning system should not only report whether an epidemic has occurred, its scope, extent, and impact but also provide policy recommendations based on epidemic development. These include whether silent prevention and control is needed, the extent and scope of control measures, predictions of subsequent impacts, and the timing of ending control measures and their consequences.

Section 2.3: Key Technical Issues

The future surveillance and early warning system needs to achieve comprehensive surveillance, early detection, rapid diagnosis, and accurate early warning for new infectious diseases. It is necessary to vigorously develop cutting-edge core cross-cutting technologies, integrate patient consultation information, pathogen identification information, global infectious disease distribution information, and multi-source big data (e.g., societal, population, climate, vector organisms), develop a new generation of infectious disease epidemic surveillance technology, and establish a network system for multi-dimensional data fusion, intelligent analysis, and sensitive epidemic detection. This will provide scientific and technological support for building a nationwide automatic positioning, identification, and early warning system for new epidemics. Key technical areas include, but are not limited to:

1. Disruptive Technologies Shifting Defense Response from Passive to Active

Develop a technical system for predicting pathogen-host adaptability evolution and cross-species variation models. Enable intelligent tracking of the impact of key amino acid mutations on transmissibility, pathogenicity, and immune escape. Implement real-time assessment of pathogen mutation characteristics, evolutionary trends, and host-specific mutation spectra to timely capture high-risk pathogens. Develop disruptive technologies for tracing and analyzing the origins and evolution of unknown/potential EID pathogens. Conduct in-depth studies of prototype pathogens from key monitored pathogen families. Develop breakthrough technologies such as mRNA, CRISPR/Cas, and novel large-scale rapid testing to prepare technical reserves for monitoring "Disease X". Using metagenomic sequencing technology as a lever, establish breakthrough technologies for artificial pathogen identification and traceability, and forward-looking surveillance and early warning of new pathogenic mutations and variant evolution directions. Build intelligent risk deduction technology based on historical patterns, conduct autonomous deduction analysis on potential risks, provide dynamic assessment of risk levels and accessibility probabilities, and achieve proactive surveillance, prediction, and early warning of new pathogenic variants.

2. Leapfrog Technologies for Threat Perception from Manned to Unmanned

Achieve automatic early warning of high-risk pathogens through intelligent, integrated, and home-based sensor networking and intelligent decision-making. Utilize all-weather technologies (e.g., satellites, unmanned intelligence) to achieve real-time full-dimensional coverage of monitoring objects, conduct intelligent analysis and judgment of potential risks, and ensure timely and accurate risk identification and early warning. Break through the bottleneck of bio-sensing technology, relying on its precise identification and conversion of specific substances or processes to make pathogen detection faster, more accurate, and more convenient. Develop a leapfrog unmanned automated surveillance and early warning system to achieve real-time automatic assessment of the epidemic situation. Develop automatic capture and intelligent analysis early warning technology for early diagnosis information of infectious diseases in high-risk groups. Collect patient symptoms, physical signs, examination results, and other data through multiple channels, utilize AI technology for processing and analysis, identify abnormal cases and signals, and predict unknown epidemic trends.* Establish an automatic surveillance system and a mobile symptom perception system based on real-time data streams to improve the sensitivity of early detection and achieve "alerting upon consultation, triggering attention upon diagnosis".

3. Iterative Technology for Surveillance Data from Single to Multi-Source

Build an intelligent prediction system for pathogen transmission dynamics, epidemic trends, and risks based on the fusion of multi-source data (e.g., medical, environmental, transportation, population, big data, public opinion). Employ reinforcement learning algorithms to achieve active information capture for predicting the threat of new pathogenic outbreaks. Break down information barriers (e.g., between medical care, prevention, research) and build multi-source heterogeneous data integration and analysis technology for epidemic detection, correlation factor analysis, and trend prediction. Establish syndrome cluster standards integrating traditional Chinese and Western medicine, and build a short-cycle real-time epidemic prediction and long-cycle trend analysis system for EIDs. Integrate surveillance networks, population migration surveillance, AI, and internet technologies into smart city construction. Study multi-source data active learning and decision-making mechanisms, develop epidemic spread analysis and prediction technology, establish a big data analysis and intelligent decision-making system, and maximize benefits. Monitor changes in microbial communities in public gathering places and early warning points. Use precise measurement technology to create dynamic distribution maps of microbial communities, establish transmission models, reveal the causal relationship between changes in microbial communities and the evolution of infectious diseases, and assess health risks.

Chapter 3: Overview of Research in the Field of EID Surveillance and Early Warning Domestically and Internationally

Section 3.1: Comparison of Current Status and Capabilities at Home and Abroad

1. International Development Status and Trends

Major Western countries continuously collect global/regional information on pathogens, host animals, and vector organisms, gather microbial resources, and conduct risk assessments. They maintain leadership in research and practice concerning the discovery of unknown pathogens, epidemic prediction and early warning, and intelligent infectious disease surveillance.

In the mid-20th century, the U.S. Centers for Disease Control and Prevention (CDC) systematically clarified the principles of disease surveillance and applied them to disease prevention and control practices for the first time. Driven by the WHO, the concept that surveillance is the cornerstone of infectious disease prevention and control gained wide acceptance. In the 1940s, the U.S. CDC began systematic disease surveillance. After the 1970s, many countries successively conducted extensive infectious disease surveillance. In 1952, WHO established the *Global Influenza Surveillance and Response System (GISRS)*, covering 110 laboratories in 82 countries to prevent and control global influenza. In the mid-to-late 1990s, increased attention was paid to syndrome surveillance for early detection of abnormalities, and the development of infectious disease surveillance systems diversified. Since 1996, WHO initiated the construction of a global epidemic alert and response system, establishing the *Global Outbreak Alert and Response Network (GOARN)* in 2000 to strengthen early surveillance and warning. Currently, the GOARN framework includes the *Global Public Health Intelligence Network (GPHIN)*, the *European Union Early Warning and Response System (EWRS/EWARS),* the *Global Influenza Platform (FluNet)*, and the *Pacific Public Health Surveillance Network (PPHSN)*, covering 79 countries and regions, as well as 153 institutions and 37 additional networks.

Developed countries like the US have gradually established infectious disease surveillance systems based on case and laboratory-confirmed information. The U.S. *National Notifiable Disease Surveillance System (NNDSS)*, initiated in 1978, currently monitors notifiable disease information from approximately 3,000 health institutions and tracks case biological samples through the *Electronic Laboratory Reporting (ELR)* system. In 1997, the U.S. Armed Forces Health Surveillance Center created the *Global Emerging Infections Surveillance and Response System (GEIS)*, covering 72 countries and 43 U.S. military bases, integrating infectious disease and health data for early epidemic detection. In 1999, the U.S. CDC established the *Laboratory Response Network (LRN)* to detect biological threats, encompassing approximately 160 laboratories. Non-traditional surveillance systems based on non-specific clinical symptoms and infectious disease-related phenomena are also evolving. The U.S. *Electronic Surveillance System for the Early Notification of Community-Based Epidemics (ESSENCE)*, established in 2000, focuses on medical data such as emergency patient complaints and drug sales to monitor early signs of community epidemics. After the 2001 anthrax terrorist incident, the construction of biological surveillance systems was significantly strengthened. Cumulative U.S. biodefense funding from fiscal year 2001 to 2011 reached US$61.86 billion.A series of biomonitoring policies were also launched, including the "21st Century Biodefense" plan, the "National Strategy for Countering Biological Threats," and the "National Biosurveillance Strategy," elevating the importance of biosecurity to unprecedented heights. After the "9/11" incident in 2001, the U.S. CDC began establishing the *Early Aberration Reporting System (EARS)*, utilizing non-conventional public health data sources, such as school/work absences, over-the-counter drug sales, 911 calls, ambulance dispatch data, and veterinary data to monitor for bioterrorism events. This system was later expanded to epidemic detection and early warning analysis of seasonal infectious diseases. In 2003, the U.S. federal government implemented the Biowatch program, covering 120 cities and more than 4,000 monitoring points to monitor pathogens in the air in real time. In the same year,the U.S.

CDC launched the *BioSense* program, which was deployed at 340 sentinel sites in 49 states to collect data in real time to prevent biosecurity incidents. These diversified surveillance systems offer comprehensive safeguards for the United States' infectious disease prevention and control capabilities.

Europe, Germany, Japan, and other regions have also established surveillance systems for notifiable infectious diseases. On this basis, they have further strengthened the role of non-traditional surveillance methods in monitoring and early warning of infectious diseases. *Europe's Influenzanet system* mobilizes public volunteers to monitor symptoms of influenza-like cases and acute respiratory infection cases, and the *Threat Tracking Tool (TTT)* monitors infectious disease threat events through media, academic websites, and professional websites of national governments or health institutions. South Korea has established an emergency department syndromic surveillance and early warning system and the *Military Active Real-time Syndrome Surveillance (MARSS)* system to monitor and assess symptoms of key infectious diseases, fully leveraging the organizational and management advantages of military medical institutions.Together, these surveillance systems and research systems have improved the global ability to prevent and control infectious diseases.

In recent years,infectious disease surveillance and early warning based on big data have developed rapidly in developed countries. The U.S. government released strategic plans for big data research and development in 2012 and 2016 respectively, with medical and health research covering the largest number of projects. At the same time, the U.S. Department of Defense invests $250 million annually to fund research into new methods of using massive amounts of data.The United Kingdo aunched their own big data research and application development strategies and measures. In 2006, the *real-time disease map (HealthMap)* established by Boston Children's Hospital in the United States integrates data from various electronic sources, including news media, professional records, and official alerts. It uses automated data mining analysisandartificial intelligence assistance to classify warnings by location and disease, marking them on an interactive map.It successfully predicted the 2014 Ebola epidemic in West

Africa.The *Google Flu Trends project*, which operated from 2008 to 2015, predicted influenza outbreaks based on Google users' web searches. After the outbreak of COVID-19,the *Johns Hopkins University Coronavirus Resource Center (CRC)* established a COVID-19 map in 2020 to summarize global COVID-19 data, including infection cases, deaths, recovered cases, etc., and analyzed them by country and county, providing timely and visual COVID-19 data to the world.At the same time, Boston Children's Hospital in the United States also launched the *Outbreaks Near Me app*, which allows people to safely and anonymously self-report symptoms and view real-time epidemic data across North America, providing early warning signals of the epidemic.

Research institutions in various countries have also conducted studies on risk assessment of pathogens. The Center for Infection and Immunity at Columbia University, the Marie Bashir Institute at the University of Sydney, and others have made progress in the study of different host-pathogen groups, utilizing cutting-edge technologies such as deep sequencing, single-molecule sequencing, metagenomic analysis, etc., combined with high-performance data analysis algorithms and models to carry out the identification, characterization, monitoring, early warning, traceability, and transmission risk assessment of new pathogens. The *SpillOver* platform, developed at the University of California, Davis, evaluates the viruses, hosts, and environmental risk factors most relevant to viral spillovers based on animal virus lists to estimate their zoonotic spillover and pandemic potential. Currently, 887 animal viruses have been tested, and their risks are ranked.

2. Domestic Development Status and Trends

As early as 1957, China established the National Influenza Center based on the Influenza Division of the Institute of Virology at the Chinese Academy of Preventive Medicine.In 1981, the National Influenza Center joined the WHO Global Influenza Surveillance Network. Since 2000,the Chinese Ministry of Health has cooperated with WHO to carry out a 10-year influenza surveillance cooperation project, which has expanded to cover 63 network laboratories and197 sentinel hospitals in 31 provinces (municipalities directly under the Central Government, autonomous regions), establishing an influenza surveillance network primarily based on influenza-like case reporting and virus isolation.In recent years, China's public health system has been continuously developing in EID surveillance and early warning, especially playing a key role in the early detection and source tracing and early warning of avian influenza and COVID-19.The *National Notifiable Disease Reporting System (NNDRS)* established in 2004 enablesreal-time, online, direct reporting based on medical institutions, and conducts comprehensive surveillance of cases, diagnosis, and epidemiological information, thereby obtaining data on the incidence and death of infectious diseases in the population. Meanwhile, the *China Infectious Disease Automated-Alert and Response System (CIDARS)*developed by the Chinese CDC in 2005, which consists of four parts: anomaly detection, signal generation, signal dissemination, and signal response information feedback. It can promptly distribute early warning signals of specific infectious diseases to disease prevention and control agencies at all levels and relevant personnel. *CIDARS* provides real-time alerts for key infectious diseases such as COVID-19, plague, cholera, and measles, etc., and daily alerts for common infectious diseases such asinfluenzaand dengue fever, etc., providing strong support for China's infectious disease prevention and control work.

In 2005, the Chinese CDC established a monitoring system for major infectious diseases such as AIDS and tuberculosis, as well as key infectious diseases like plague and cholera. This system strengthens surveillance on nearly 40 types of diseases, including most notifiable infectious diseases and key non-notifiable ones. Based on case reports from sentinel hospitals, individual investigations and laboratory testing are conducted, or relevant data such as animal hosts, transmission vectors, environmental factors, and pathogen resistance are collected. Since 2009, relying on the infectious disease technology platform projects established by major national science and technology special projects, China has established surveillance systems for five major syndromes in multiple provinces, including fever respiratory syndrome, diarrhea syndrome, fever with rash syndrome, fever with hemorrhage syndrome, and encephalitis/meningitis syndrome, promoting the application of syndrome monitoring in our country. In addition, the Chinese CDC launched the Monitoring Project for Health Hazards in Public Places in 2016 and established a supporting information management system, covering 117 monitoring cities (districts) in 31 provinces, municipalities, autonomous regions and the Xinjiang Production and Construction Corps. This project aims to collect basic information on public places, monitoring results of health hazard factors and health status of employees, and provide scientific basis for preventing health hazard events in public spaces.

The PLA CDC has established a comprehensive military infectious disease pathogen surveillance system covering hundreds of medical and health institutions across the armed forces. This system has made significant contributions to controlling infectious disease outbreaks within the military and safeguarding the health of officers and soldiers. Since 2016, a national military-civilian integrated infectious disease surveillance network has been developed and established. Initial integration efforts encompass the infectious disease surveillance networks of ten key entities: the PLA Health Information Center, all levels of infectious disease surveillance network laboratories of the PLA, Chinese CDC, China Animal Disease Prevention and Control Center, Chinese Academy of Inspection and Quarantine, Chinese Academy of Sciences, National Wildlife Focal Disease Monitoring Station, Ministry of Ecology and Environment (formerly Ministry of Environmental Protection), and the Nanjing Institute of Environmental Sciences. This integration has established a prototype national biosecurity monitoring network and early warning platform. The platform aims to unify systems including the national infectious disease surveillance system, the military infectious disease surveillance system, the animal disease surveillance system, and wildlife surveillance, among others. Initial progress includes establishing unified standards and data transformation methods through multi-source data extraction and integration technology. Additionally, biosecurity analysis and early warning methods—such as big data mining, multi-sequence emergency warning, and spatio-temporal transmission dynamics—have been developed. The supporting big data platform and intelligent analysis/early warning technologies provide the technical foundation for achieving early, highly timely, sensitive, and accurate warnings based on multiple real-time bio-monitoring data streams.

With the reform and adjustment of the national disease control agency, the National Bureau of Disease Control and Prevention (NBDP), established in 2021, has clarified its responsibilities. These include planning and guiding the construction of an infectious disease epidemic surveillance and early warning system; organizing and conducting epidemic monitoring and risk assessments; and establishing and improving cross-departmental and cross-regional epidemic information notification and sharing mechanisms. Under the NBDP's leadership, a functional study of the public health system has been conducted to identify weaknesses in surveillance systems for acute respiratory/intestinal infectious diseases, fever syndromes, and unexplained pneumonia at all administrative levels, with corresponding recommendations for system enhancement proposed. Concurrently, we have strengthened analysis of traceability leadership mechanisms and technical capacities, fully leveraged National Biosecurity Coordination Mechanism, reinforced research on unified leadership frameworks, and clarified legal responsibilities—all to improve the timeliness of future monitoring, traceability, and early warning.

3. Comparative Analysis

Theoretical research and practical application in the field of EID surveillance and early warning commenced earlier and advanced more rapidly internationally than in China. By the late 20th century, developed countries, led by the United States, recognized the critical importance of pathogen laboratory monitoring grounded in microbiology, inspection, and detection technologies. Leveraging their overseas military bases, they began establishing global pathogen surveillance networks. At the dawn of the 21st century, Western nations progressively elevated EID surveillance, early warning, and broader biosafety monitoring to the level of national strategy. Concurrently, surveillance methodologies underwent rapid diversification and evolution. Surveillance and early warning systems moved beyond sole reliance on passive case monitoring and laboratory diagnosis. Non-traditional approaches focusing on non-specific clinical symptoms and infectious disease-related phenomena experienced significant development. Platforms integrating big data, artificial intelligence (AI), automated diagnostics, nucleic acid sequencing, and pathogen detection technologies combined with gene editing, nucleic acid amplification, and biosensing emerged. These integrated systems demonstrate the capability to detect major infectious disease outbreaks and potential bioterrorism attacks in nearly real-time, accurately predict disease occurrence and spread, and exhibit substantial utility in infectious disease monitoring and early warning applications.

China's research and practice in the surveillance and early warning of emerging infectious diseases started late, with slow progress in the early stage and gradual acceleration in the later stage. However, there remains a notable gap in theory, technology, and application compared to developed countries globally. By the end of the 20th century, China had achieved significant successes in the targeted prevention and control of traditional infectious diseases such as smallpox, poliomyelitis, plague, schistosomiasis, malaria, and leprosy. Concurrently, Western countries had gradually established comprehensive infectious disease surveillance systems and pathogen detection laboratories. Notably, the United States had begun conducting global infectious disease surveillance through its overseas laboratory network.

After defeating the SARS epidemic in 2003, China revised the Law of the People's Republic of China on the Prevention and Control of Infectious Diseases, promulgated regulations such as the Regulations on Emergency Response to Public Health Emergencies and the Emergency Response Law of the People's Republic of China, and issued the National Public Health Emergency Response Plan. These measures provided a solid legal foundation and practical guidance for infectious disease prevention and control in China, ensuring governance by law. Meanwhile, a nationwide reporting system for 41 notifiable infectious diseases (i.e., the online direct reporting system), an automatic early warning and response system for infectious diseases, and an infectious disease laboratory network were gradually established.

Abroad, developed countries had begun exploring the use of multi-channel electronic data—such as outpatient medical records, school/work absenteeism records, over-the-counter drug sales data, 911 calls, ambulance dispatch records, and veterinary data—for active infectious disease surveillance. China closely followed suit, establishing a surveillance system for five major syndromes and health risk factors in public places. It also promoted the integration of multiple military-civilian surveillance systems and built a big data surveillance platform. However, China still lags in core technologies such as biological detection and big data analysis.

After the 2019 COVID-19 epidemic, EID surveillance and biosecurity were elevated to the national strategic level, with enhancing surveillance and early warning capabilities becoming a top priority for strengthening the public health system. The National Disease Control and Prevention Administration, established after the health system reform, will lead the construction of the infectious disease epidemic surveillance and early warning system. Currently, it has begun to establish a pilot monitoring system for multiple pathogens of respiratory infectious diseases based on emergency and inpatient data.

Section 3.2: Feasibility Analysis of Accelerating the Construction of the EID Surveillance and Early Warning System.

At the institutional level, within the framework of China's national governance system with Chinese characteristics, the Party's centralized and unified leadership ensures the efficient implementation of all policy decisions and deployments. The institutional advantage of pooling resources to tackle major tasks enables rapid concentration of cross-sectoral resources and effective responses to challenges. By elevating biosecurity to a national strategic priority and drawing on valuable experience accumulated from the SARS and COVID-19 epidemics, the government has established a solid institutional foundation for EID surveillance and early warning research.

At the policy level, the central government has consistently prioritized public health and biosecurity, emphasizing the critical importance of strengthening the disease prevention and control system. It has explicitly put forward specific requirements for enhancing surveillance and early warning capabilities against EIDs. In terms of funding, the country's 14th Five-Year Plan (2021-2025) has significantly increased investment in infectious disease research: funding for key infectious disease surveillance projects grew by 243% year-on-year, with total investment exceeding ¥1.8 billion ($250 million) in 2023, providing robust financial support for scientific research.

At the systemic level, China has established a comprehensive surveillance framework comprising an infectious disease reporting system, an automatic early warning and response system, and an infectious disease laboratory network. The four-tiered disease prevention and control system (national, provincial, municipal, and county levels) provides strong institutional support for surveillance and early warning research. Relying on major platforms such as national laboratories, cutting-edge technologies—including basic infectious disease research, big data analytics, and artificial intelligence—have been continuously advanced. Meanwhile, the steady implementation of national science and technology major projects for EID prevention and control has provided technical underpinnings for surveillance and early warning. In terms of talent development, reforms in public health education and the practical experience gained from the COVID-19 response have nurtured excellent research teams and high-level clinical experts, injecting sustained momentum into the development of surveillance and early warning capabilities.

Chapter 4: Development Ideas and Policy Recommendations

Currently, the Ministry of Science and Technology has formulated a draft implementation plan for a major national science and technology project on the EID prevention and control. Surveillance and early warning have been designated as key tasks under the overall goals. It is recommended to adopt extraordinary measures in task deployment and organizational implementation to accelerate progress.

Section 4.1: Strategic Level: Firmly Anchoring the Overall Objective of Self-Reliance and Operational Control

The high-quality development and high-level operation of the EID surveillance and early warning system—ultimately aimed at fostering new operational capabilities and generating new productive forces—constitute a glorious yet arduous mission. The independence and controllability of technologies, equipment, and capabilities serve as both the foundational premise and the overarching objective. This necessitates the following approaches:

- **Insisting on theoretical and technological independence:** Achieving fundamental breakthroughs in key theories and core technologies to eliminate reliance on external sources.
- **Leveraging the new national system**: Drawing on the successful model of major projects (e.g., manned space program), pooling national resources, formulating extraordinary measures, organizing collaborative research, striving for substantial breakthroughs, and rapidly producing high-level equipment and products to enhance EID surveillance and early warning capabilities.
- **Aligning with national strategic capabilities**: Coordinating the development of the bio-economy and biosecurity defense, adopting methods like "civilian support for the military" and "military-civilian integration" to maximize strategic advantages through deep military-civilian integration and secure strategic initiative.

In response to future EID threats and aligned with the holistic national security concept, systematically catalog the problem spectrum, demand spectrum, and technology spectrum. Address weaknesses, solidify foundations, leverage strengths, and strengthen "peacetime" technical reserves and capacity building. This ensures rapid and precise transformation into "wartime" response capabilities during major outbreaks, enabling proactive and composed handling of major emergencies.

Section 4.2: Operational Level: Adhering to Open Cooperation and Jointly Build a System Serving Human Health

In an era of increasing global interconnectedness, pathogens recognize no borders, and diseases discriminate against no race. The COVID-19 pandemic has unequivocally demonstrated that global health security is indivisible—prosperity and peril are shared collectively. As the world's largest developing nation and second-largest economy, China remains steadfast in upholding the principles of mutual respect, equitable cooperation, and win-win engagement. By strengthening international collaboration, China advocates for an enabling global governance environment, ensuring its constructive role in advancing a shared vision for global health security.

1. Expanding International Surveillance Networks Through Strategic Cooperation

A robust global EID surveillance and early warning system is not merely a national imperative but a cornerstone of effective international biosecurity governance. China must proactively integrate into and help shape the global surveillance architecture by:

- **Deepening bilateral and multilateral partnerships** with leading public health systems, including those of the U.S., EU, Japan, and ASEAN nations, to establish stable mechanisms for intelligence-sharing, joint research, and technological exchange.
- **Enhancing participation in WHO-coordinated initiatives**, such as the Global Outbreak Alert and Response Network (GOARN), while contributing pathogen surveillance data to international databases.

- **Supporting capacity-building in low-resource regions**, particularly in Africa, through technical assistance, infrastructure development, and knowledge transfer to fortify early detection and response capabilities against cross-border health threats.

2. Forward Deployment: Establishing Overseas Sentinel Surveillance Nodes

- **Deploying overseas sentinel monitoring stations** in key regions with high epidemiological risk. These facilities—ranging from diagnostic clinics to mobile biosurveillance units—should operate through public-private partnerships, leveraging both governmental oversight and private-sector agility.
- **Leveraging the Belt and Road Initiative (BRI)** to institutionalize long-term collaborative frameworks with partner nations, facilitating joint pathogen surveillance, real-time data exchange, and coordinated response protocols for high-consequence infectious diseases.
- **Mapping the systematic Pathogen** in High-Incidence Zones of Animal Infectious Diseases， Identifying Reservoirs of High-Risk Microorganisms for Proactive Risk Assessment and Mitigation Strategies.

3. Talent Inclusivity: Attracting Global Expertise for China’s Biosecurity Ecosystem

The sophistication of a nation’s infectious disease surveillance system is inextricably linked to its ability to cultivate and retain world-class scientific talent. To this end, China should:

- **Implement competitive incentive schemes** to attract top-tier overseas researchers, including streamlined visa policies, endowed research chairs, and internationally benchmarked compensation packages.
- **Foster public-private innovation hubs** that provide cutting-edge technological platforms and entrepreneurial freedom, encouraging diaspora scientists and foreign experts to contribute to China’s biosecurity research landscape.
- **Promote institutional linkages** between Chinese universities, research centers, and global

health organizations to facilitate joint training programs, cross-border research consortia, and technology co-development initiatives.

Section 4.3: tactical level: Integrating Peacetime-Wartime operations through multi-point convergence for intelligent triggered Surveillance and early warning system

To address future emerging public health threats in alignment with the comprehensive national security paradigm, we propose a systematic framework encompassing: (1) problem identification matrix, (2) demand assessment protocol, and (3) technological capability mapping. This tripartite approach facilitates targeted capacity building through strategic reinforcement of technical reserves during routine operations ("peacetime mode"), ensuring seamless transition to emergency response capabilities ("wartime mode") during major outbreaks. The implementation framework comprises three synergistic components:

1. Peacetime-Wartime Integration: Build a Robust Military-Civilian Integrated Surveillance and Early Warning System

- **Establish a dual-center (military and civilian) EID surveillance and early warning system** with integrated information technology, leveraging respective advantages to enhance effectiveness.
- **Establish a mutual training mechanism** for military and civilian personnel, conduct practical exercises, and reserve emergency response personnel.
- **Conduct regular military-civilian joint exercises** based on actual prevention and control tasks, deepening and refining integration.
- **Explore embedding liaison officers** within each other's disease control forces to achieve deep integration and accumulate experience for seamless peacetime-to-wartime transition.

2. Medical-Prevention Integration: Innovate Multi-Point Triggering Mechanisms Across Departments

- **Strengthen organizational leadership**, improve multi-departmental coordination mechanisms, integrate existing independent surveillance systems, break down administrative, technical, and information barriers at all levels, and establish data integration platforms, data analysis platforms, and real-time early warning platforms to enable the exchange of EID risk factors.
- **Further activate the sentinel role** of hospital fever clinics and explore integrating hospital fever (gastrointestinal) clinics into the dual-track operation of the disease control system.
- **Establish independent, controllable, secure, and effective information databases** (literature databases, pathogen information databases, anonymized health code and personal itinerary databases, etc.), accelerate their transformation and application, and break down barriers to adopting new technologies and products.
- **Address the conflict between privacy protection and epidemic surveillance** by clarifying boundaries for collecting and disclosing private information, strengthening research and application of information security technology, and promoting the advancement of privacy-preserving computation techniques.

3. Advance Planning: Promote Smart City Construction to Support EID Surveillance and Early Warning Services

- **Deeply integrate EID surveillance and early warning with smart city construction.** Incorporate top-level design in urban planning, embedding intelligent equipment capable of integrated pathogenic microorganism monitoring and elimination early on.
- **Revise construction standards for air supply and exhaust systems in public buildings** to improve the sensitivity of pathogen monitoring in crowded public places and reduce the risk of pathogen spread.
- **Fully utilize, mine, and develop information** from wearable devices to enhance

monitoring and information utilization for specific groups (e.g., schools, communities).

- **Task leading domestic AI and data modeling companies** with developing and upgrading surveillance and early warning models.

Table 1. The representative surveillance system in the world

Name of surveillance system	Purpose	Working principle	Initiating countries or organization	Establishment time	Surveillance range	Effects or current state	Reference
Global Influenza Surveill-anceand Response System(GISRS)	For the surveillance of influenza virus and to make recommendations around laboratory diagnostics, vaccines, and risk evaluation, and to provide global alerts	Conducting effective cooperation and sharing of viruses, data and benefits based on Member States' commitment to a global public health model	WHO	In 1952	Covering 6 collaborating centers, 4 essential regulatory laboratories, and 143 institutions in 113 WHO member states	Global mechanism of surveillance, preparedness and response for seasonal, pandemic and zoonotic influenza; Global platform for monitoring influenza epidemiology and disease; Global alert for novel influenza viruses and other respiratory pathogens	https://www.who.int/influenza/gisrslaboratory/en/

Global Outbreak Alert and Response Network (GOARN)	To rapidly respond to international biosecurity Outbreaks, to provide international public health resources to control outbreaks and public health emergencies	Conducting cooperation based on existing technical institutions and networks	WHO	In 2000	Comprising over 250 technical institutions and networks globally that respond to acute public health events with the deployment of staff and resources to affected countries	Under the coordination of the WHO Operations Support Team and the management of the Steering Committee, rapid and effective support should be provided for the prevention and control of infectious disease outbreaks and public health emergencies upon request	https://extranet.who.int/goarn/
BioSense	To enhance the national capability to rapidly detect, quantify,	Collecting electronic data from multiple governmental	US CDC	In 2003	Covering national, regional, and local health data	Establishing near real-time electronic transmission of data to local, state, and federal public health agencies	https://www.cdc.gov/mmwr/preview/mmwr

	and localize public health emergencies, particularly biologic terrorism	sources to access and analyze diagnostic and pre-diagnosed health data			sources		html/su5301a13.htm
Name of surveillance system	Purpose	Working principle	Initiating countries or organization	Establishment time	Surveillance range	Effects or current state	Reference
The Antimicrobial Resistance Monitoring and Research Program	To respond to escalating antimicrobial resistance, to aid in infection prevention and control	Using molecular characterization to understand and control the resistance of antimicrobial	the US Department of Defense	In 2009	Consistsing network of epidemiologists, bioinformaticists, microbiology researchers, policy makers,	Collecting relevant AMR data, conducting centralized molecular characterization, and using AMR characterization feedback to implement appropriate infection prevention and control measures and	https://academic.oup.com/cid/article/59/3/390/2895597

		biopharmaceuticals			hospital-based infection preventionists, and healthcare providers	influence policy	
The National Notifiable Disease Reporting System (NNDRS)	For outbreak detection and rapid response to infectious diseases	Reporting confirmed cases of legal infectious disease to their superior department	Chinese CDC	In 2003	Covering almost all of China	Less efficient；Lacking the horizontal information sharing function, and hospitals lack data comparison of patients with the same symptoms	http://www.doc88.com/p-3512171864992.html
The Chinese National Influenza Surveill ance Network (CNISN)	For surveillance and control of influenza-like cases; To strengthen the work of influenza	Carrying out etiological and epidemiological surveillance of influenza in the mainland of China	Institute for Viral Disease Control and Prevention , Chinese	In 1957	Covers 408 Network laboratories and 554 sentinel hospitals	Playing an important role in the surveillance and control of influenza-like cases, notably in the fight against avian influenza A(H7N9)	http://ivdc.chinacdc.cn/cnic/en/Aboutus/

	surveillance and disease control		CDC				
The Laboratory Response Network (LRN)	Detecting biothreats through identifying pathogen, analyzing its origin , virulence, and antimicrobial-resistane	Laboratory-based surveillance: based on detection capabilities at a molecular level, normally through network laboratories	US CDC, the Federal Bureau of Investigation, and the Association of Public Health Laboratories	In 1999	Covers about 160 reference Laboratories including state and local public health, veterinary, military, and international labs.	Playing an instrumental role in improving domestic public health infrastructure by helping to boost laboratory capacity in the U.S.	http://emergency.cdc.gov/lrn/index.asp
Name of surveillance system	Purpose	Working principle	Initiating countries or	Establishment time	Surveillance range	Effects or current state	Reference

			organization				
BioWatch	The Department of Homeland Security's biowatch Program provides early detection of a bioterrorism event and helps communities prepare a coordinated response. The combination of detection, rapid notification, and	Analyzing biological threats through sampling aerosols from key areas	US	In 2003	Environment-based surveillance: promoting the detection of aerosolized biological agents.	Environmental detection systems comprise the remote detection of aerosol clouds and environmental point detection systems	https://www.dhs.gov/publication/biowatch-program-factsheet

	response planning helps federal, state, and local decision-makers take steps to save lives and mitigate damage.						
The Early Aberration Reporting System （EARS）	To analyze symptoms monitoring data from various sources in order to detect bioterrorism incidents in time. Later extended to detection of outbreaks and early warning	Web-based surveillance: utilizing nontraditional public health data sources	Developed by the U.S. Centers for Disease Control and Prevention (CDC)	In 2002	This EARS system applies aberration detection algorithms to New Zealand notifiable disease surveillance data and flags anomalies.	Over-the-counter electrolyte sales preceded hospital visits for respiratory or gastrointestinal illnesses by 2.4 weeks	http://www.bt.cdc.gov/surveillance/ears/

	analysis of seasonal infectious diseases.						
Electronic Surveillance System for Early Notification of Community-based Epidemics	Assist public health departments in detecting and monitoring the outbreak of health events and making decisions	receive traditional and non-traditional data sources electronically, complete data ingestion or preprocessing; apply various temporal and spatial alert algorithms to each dataset	Walter Reed Army Institute of Research (WRAIR) and Johns Hopkins University Applied Physics Laboratory (JHU/APL)	In 2000	Monitor medical related data such as emergency patient complaints, drug sales, school absentee records, health hotline records	After the "September 11 attacks", the version of ESSENCE has been implemented in the Department of Defense (DoD), Veterans Administration (VA), Centers for Disease Control and Prevention (CDC) and state and local public health agencies across the United States, and implemented internationally through cooperative efforts of the Department of Defense	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8277331/
Name of surveillance	Purpose	Working principle	Initiating	Establishment	Surveillance range	Effects or current state	Reference

system			countries or organization	ent time			
Google Flu Trends	To predict flu outbreaks based on web searches of google users.	Through monitoring daily health-searching behaviors.	Google	2008-2015	The areas that users could access Google Flu Trends	Although it was reported to be able to, its predictions were doubted not accurate enough, its predictions were doubted not accurate enough, with the predicting results much larger than the actual influenza-like illness (ILI) provided by the US CDC.	https://blogs.scientificamerican.com/news-blog/google-flu-trends-your-own-disease-2008-11-12/

HealthMap	To classify warnings by location and disease, and label them on the interactive map.	Integrating data from various electronic sources, including news media, professional records, and official warnings, and using automated data mining and analysis. Aided by artificial intelligence	Developed by Boston Children Hospital, US	In 2006	worldwide	Alarmed the COVID-19 as early as on December 30, 2019	https://www.sciencemag.org/news/2020/05/artificial-intelligence-systems-aim-sniff-out-signs-covid- 19-outbreaks
Global Emerging Infections Surveillance （GEIS)	To improve infectious disease surveillance, prevention, and response; To	Through strengthening surveillance, outbreak response, collaboration, and	Department of Defense (DoD), US	In 1997	Focusing areas in concert with Geographic Combatant Commands	Addressing militarily relevant infectious disease threats and informing force health protection (FHP) decision making	https://health.mil/Military-Health-Topics/Com

	support surveillance and outbreak response efforts in four infectious disease; To mitigate the threat of emerging infectious diseases to the US. military through a global laboratory network.	coordination of the global DoD laboratory network.			(GCC) priorities: antimicrobial resistant infections (including sexually transmitted infections), enteric infections, febrile and vector-borne infections, and respiratory infections.		bat-Support/Armed-Forces-Health-Surveillance-Branch/Global-Emerging-Infections-Surveillance-and-Response
Name of surveillance system	Purpose	Working principle	Initiating countries or	Establishment time	Surveillance range	Effects or current state	Reference

			organization				
COVID-19 map	To provide timely and visualized COVID-19 data for the access of the world including researchers,public health authorities, and the general public.	All data collected and displayed are made freely available through a GitHub repository, along with the feature layers of the dashboard.	Developed by the Johns Hopkins Coronavirus Resource Center (CRC)	In 2020	Global COVID-19 including the cases of infected, death, recovered, and etc, categorized by countries and county.	Over 1200 citations in the first 4 months since its publication. Considered authoritative as source of global COVID-19 epidemiological data.	https://coronavirus.jhu.edu/map.html
EpiPulse the Europe an surveillance portal for infectious diseases	For European public health authorities and global partners to collect, analyse, share, and discuss	Collection, analysis and dissemination of indicator and event-based surveillance data	European Center of Disease Control and Prevention	2021.6.22	Global epidemic intelligence, whole-genome sequencing, and health	Integrating several surveillance systems that were previously independent (The European Surveillance System (TESSy), the five Epidemic Intelligence	https://www.ecdc.europa.eu/en/publications-data/epipuls

	infectious disease data for threat detection, monitoring, risk assessment and outbreak response.	on infectious diseases and associated health issues, including global epidemic intelligence, whole-genome sequencing, and health determinants.			determinants.	Information System (EPIS) platforms and the Threat Tracking Tool (TTT)), provides new functionalities and seamless access to data in a single platform.	e-european-surveillance-portal-infectious-diseases

Table 2. The representative surveillance organization, program or regulation in the world

Surveillance organization, program or regulation	Purpose	Iniciating Countries or Organization	Surveillance range	Iniciated or revised year	Effects or Current state	Reference
International Health Regulations (IHR) 2015	For surveillance system tracking.	WHO	Expanding specific high-priority infectious diseases to include novel and changing public health risks	Revised in 2005	More than a guideline but not legislation; it relies on individual countries to self-report and is not strictly enforceable	https://www.who.int/ihr/finalversion9Nov07.pdf
The National Strategy for Countering Biological Threats	To manage the risks from occurring deliberately diseases naturally and introduced	White House	Currently, it has established more than 4,000 surveillance sites in more than 30 major US cities, and has an international surveillance network that impacts at least 92 countries	In 2009		https://irp.fas.org/congress/2010_hr/biothreat.pdf

The European Center of Disease Control and Prevention	For timely alert of infectious disease outbreaks	Established	Covers 46 diseases including severe acute respiratory syndrome, West Nile fever, and avian influenza	In 2004	Is integrated into the national crisis prevention system to support early evaluation and decision-making in response to potential biosecurity threats	https://www.ecdc.europa.eu
Integrated Disease Surveillance and Response (IDSR) programs	To make surveillance and laboratory data more usable, helping public health managers and decision-makers improve detection and response to the leading causes of	With funding from USAID, CDC's IDSR team collaborated with WHO/AFRO to lead the development of the IDSR framework and the design and	43 countries in the African region	In 1988	The US CDC has played a leading role in designing, developing, implementing, monitoring and evaluating IDSR since its inception in 1988.	https://pubmed.ncbi.nlm.nih.gov/30496177

	illness, death, and disability in African countries.	development of the Technical Guidelines for Integrated Disease Surveillance and the IDSR Training Modules				
Africa CDC	To support public health initiatives of Member States and strengthen the capacity of their public health institutions to detect, prevent, control and respond quickly and effectively to disease	A specialized technical institution of the African Union	Supporting African Union Member States	2017.1	greatly improving surveillance, emergency response, and preventon of infectious diseases	https://africacdc.org/

	threats.					
Surveillance organization, program or regulation	Purpose	Iniciating Countries or Organization	Surveillance range	Iniciated or revised year	Effects or Current state	Reference
The National Surveillance Integration Center (NBIC)	To integrate surveillance information and support an inter-agency surveillance community coordination and interoperability across agency borders to meet the surveillance	As part of the DHS Office of Health Affairs, US	Serves as a bridge between federal, state, local, territorial, and tribal partners to integrate information from thousands of sources about biological threats to human, animal, plant, and environmental health, improving early arning and situational awareness.	In 1988	To enable early warning and shared situational awareness of acute biological events and support better decisions through rapid identification, characterization, localization, and tracking.	https://www.dhs.gov/taxonomy/term/2649/all/feed

	requirements in terms of timeliness, sensitivity, specificity, and routine analysis of data					

Table 3 Infectious Disease Surveillance System in China

Name of surveillance system	Purpose	Working principle	Establishment time	Surveillance range	Effects or current state	Reference
National Notifiable Disease Reporting System (NNDRS)	Used for the outbreak detection and rapid response of infectious diseases	Report confirmed cases of notifiable infectious diseases to regulatory authorities	In 2003	Almost covering the whole territory of China	Inefficient; lack of horizontal information sharing function, hospitals can not realize the data comparison of patients with the same symptoms	http://www.doc88.com/p-3512171864992.html
National Communicable Disease Automated Alert and Response System (CIDARS)	Used to assist the Center for Disease Control and Prevention (CDC) in the early detection of communicable	Using different warning algorithms for different diseases, continuously automatic analysis and calculation of national notifiable infectious disease	In 2008	Almost covering the whole territory of China	Achieve automatic early warning when there is an abnormal increase in cases, a crowd gathering, or occurrence of sensitive cases (such as plague, COVID-19, human infection with avian influenza,	https://www.sciencedirect.com/science/article/pii/B9780128123430000072

	disease outbreaks	surveillance data, send signals of abnormal case increases or clusters found to local county (district) CDCs, local CDCs report results to the system after investigation and verification			etc.), but the proportion of suspected signals is low, and the timeliness of early warning is insufficient	
Laboratory network for pathogen spectrum monitoring based on infectious disease syndromes	Conduct surveillance on multiple pathogens for five major syndromes including fever with respiratory symptoms, diarrhea, fever with	Master the transmission characteristics and basic patterns of variation and migration of the pathogenic spectrum causing the five syndromes in China	In 2008	Have 12 core laboratories, covering 91 provincial and municipal regional laboratories and more	The detection and monitoring cover more than 90 important pathogens for the five major syndromes of infectious diseases, which played a key role in the timely discovery and confirmation of the pathogens of H7N9 avian influenza and COVID-19 epidemics	http://www.qikan.com.cn/newarticleinfo/jzyb2022210182-1.html

	rash, fever with bleeding, and encephalitis/meningitis			than 800 hospital laboratories		
Name of surveillance system	Purpose	Working principle	Establishment time	Surveillance range	Effects or current state	Reference
Monitoring of health hazards in public places	Effectively prevent the occurrence of health hazards in public places and provide scientific evidence to improve the decision-making ability of relevant	Collect the basic situation of five types of public places including hotels, swimming pools, bathhouses, beauty salons (barbershops) and waiting rooms, the results of monitoring health hazard factors (physical, chemical and	In 2016	Cover 117 monitoring cities (districts) in 31 provinces, direct-controlled municipalities, autonomous	Formulate a series of monitoring technical documents to standardize the implementation of monitoring work; promote the construction of personnel teams in disease control institutions, enhance the monitoring capability of public places; establish an information management	https://iehs.chinacdc.cn/jcdc/gcsjc/201811/t20181116_197334.html

	government departments	microbial indicators) and the results of surveys on the health status of employees		regions and Xinjiang Production and Construction Corps across the country	system for monitoring projects of health hazards in public places	
China National Influenza Surveillance Network (CNISN)	Real-time monitoring of influenza activity levels and epidemic trends, tracking influenza variant viruses, timely discovery of new influenza viruses, providing a basis for the	Carry out influenza etiology and epidemiological surveillance in mainland China	In 2000	Covering 554 sentinel hospitals and more than 1000 network laboratories nationwide, national network laboratories covering all	Playing an important role in responding to the influenza pandemic and influenza prevention and control. Based on this network, China has successfully dealt with the influenza A H1N1 pandemic and outbreaks of H7N9/H10N8/H5N6 avian influenza, among others.	http://ivdc.chinacdc.cn/cnic/en/Aboutus/

	recommendation of influenza vaccine strains and the use of antiviral drugs in China and globally			municipal CDCs		
Single disease surveillance system for major diseases such as AIDS and tuberculosis, and key infectious diseases such as plague and cholera	Comprehensive surveillance of major and key infectious diseases, case management, animal hosts or transmission vectors, and environmental risk factors	Intensive surveillance has been carried out on nearly 40 diseases, including most of the notifiable infectious diseases and key non-notifiable infectious diseases. Based on the medical records of sentinel hospitals, case investigation and laboratory testing were	In 2005	Nearly 3,000 national surveillance sites for major and key infectious diseases have been set up. Different provinces will carry out	For major infectious diseases such as AIDS and tuberculosis, a case registration management information system is established based on case reports. For key infectious diseases, the combination of active surveillance and passive surveillance, and the combination of community, hospital, laboratory and field surveillance are used to track	Chinese Center for Disease Control and Prevention. Report on infectious disease surveillance in China in 2022[M]. Beijing: 2023.

		carried out, or relevant data on animal hosts, transmission vectors, environment, and pathogen resistance were collected		corresponding surveillance of infectious diseases according to different epidemic regions, transmission routes and risks. Vector surveillance is also being carried out in 19 provinces across the country.	pathogen mutation in time and dynamically monitor and warn the epidemic trend of diseases.	