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Review of Biosurveillance and Early Warning Capabilities in the United States and Other Developed Countries

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Abstract: Surveillance and early warning are key aspects of a country's biosecurity capability. In this paper, we investigate the overall status of the USA and other countries' research and development regarding their own capabilities for biosurveillance. We make several recommendations to strengthen China's biosurveillance capability, including strategic planning, mechanism reform, personnel training, and infrastructure platform construction. In addition, we comment on strengthening the supporting role of science and technology.

Keywords: biosurveillance; early warning; biodetection; biosecurity; capability building

1 Introduction

In the 21st century, with the drastic changes in the international development and security situation, biothreats have become one of the major security threats worldwide. Since the Eighteenth National Congress of the Communist Party of China, the Central Committee has put forward a policy of emphasizing security and development and arranged a comprehensive national security system. In view of the biothreat situation in China, it is imperative to strengthen the biosurveillance and early warning capabilities of the country. The development of biosurveillance capability is a complicated project, and there is much to learn from the experiences of other countries. In this paper, the overall status of research and development of the biosurveillance capabilities of the USA and other developed countries is reviewed, with the expectation that some of the resultant knowledge can be used to strengthen biosurveillance capability development in China.

2 Surveillance and early warning are key parts of biosecurity capability

Biosecurity describes the status and capability of a country to effectively cope with the impacts and threats of biology and biotechnology and ensure and protect its own security and interests in this era of globalization. Biosurveillance and early warning capabilities are the most important parts of biosecurity and are not only the "sentries" that identify risk but also the first "shields" for coping with threats, the primary basis of implementing active defense, and an important demonstration of the advanced nature of national biosecurity capabilities [1].

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Biosurveillance and early warning are facility systems that integrate technology, equipment, and information, and functional systems in which detection, surveillance, and early warning are highly correlated. Biodetection, mainly including morphologic, physical, chemical, immunological, and nucleic acid detection, is the basis of biosurveillance. In recent years, such methods have been combined with physics, chemistry, informatics, and advanced manufacturing to create biosensors, biochips, biomass spectrometry, and other biodetection technologies and equipment, enriching biodetection methods, improving the biodetection level, and promoting the development of further biodetection equipment. Biosurveillance mainly includes case, laboratory network, environmental, symptom, and event surveillance, as well as other methods with different characteristics, applicable in different environments. However, biodetection remains the technological basis. Furthermore, with the rapid development of computer and information technology, informationizing features are becoming increasingly prominent in current biosurveillance, and its functions have changed from collection, transmission, and summarization of data to comprehensive surveillance incorporating multiple functions such as full-spectrum surveillance, information integration, mathematical modeling, data mining, risk evaluation, and situation awareness. Hence, biosurveillance has become increasingly important in emergency management of biological events and is now the comprehensive information platform to aid decision making.

A biosurveillance system must have basic characteristics such as accuracy, sensitivity, and promptness, and in practice, multiple methods are often required to create a comprehensive system. The abovementioned capabilities for detection, surveillance, and early warning are highly correlated, unable to be separated entirely under many circumstances, and often functioning in parallel. Therefore, these capabilities can be collectively referred to as biosurveillance and early warning during the development of biosurveillance capability in China.

3 Developmental situation and trends in biosurveillance in foreign countries

3.1 Biosurveillance has been incorporated into national security strategy

After the anthrax attacks in 2001, the USA enacted many strategies and laws related to biosecurity and created multiple national biosecurity strategic plans such as the *National Biodefense Strategy*, *National Strategy for Countering Biothreats*, and *National Strategy for Biosurveillance*. The *National Biosurveillance Science Technology Roadmap*, issued in June 2013, focused on comprehensively strengthening and upgrading national biosurveillance and early warning systems, such that the USA completed the comprehensive national strategic deployment of strengthened biosecurity capability [2]. Moreover, the UK, France, Germany, Russia, and other countries have developed strategic planning for defending against biothreats.

3.2 Development of bioagent detection equipment

Biodetection equipment is largely developed along with bioweapon defense. In recent years, owing to the need to defend against bioterrorism, the USA has hastened the development of biosurveillance equipment and systems, including the Joint Biological Agent Identification and Diagnostic System (JBAIDS), M31 Biological Integrated Detection System (BIDS), and M93 Nuclear, Biological, and Chemical Reconnaissance System [3]. Further, Britain has developed the Integrated Biological Detection System (IBDS) and Marine Biological Detection System (MBDS); France has developed the Biological Alarm Monitor (BAM); Germany has developed the Assay Processing and Specific Identification System (APSIS), biological identification system, and so on. The main characteristics and trends of bioagent detection equipment development in the USA and other developed countries are: ① a focus on development of technology to ensure that the equipment is efficient and sensitive; ② attachment of importance to modular design to integrate the overall advantages; ③ reduction of the logistic burden to support the development of bioagent detection equipment; and ④ emphasis on integration to improve the level of securing the information network.

3.3 Multiple national biosurveillance systems have been established

National biosurveillance mainly includes surveillance of cases, laboratory networks, environment, symptoms, events, and other methods; passive surveillance is combined with active surveillance to orient the whole country and foreign mission areas. Typical systems in the USA include the multilayered, multidepartment, multifunctional, nationwide, and highly networked Laboratory Response Network (LRN) for biothreats, BioWatch and BioSense programs, and syndromic surveillance system. Other such systems are the French 2SE FAG system, British military prototype remote illness and symptom monitor (PRISM), Australian sentinel practice research network (ASPREN), and Canadian global public health intelligence network (GPHIN) [4–7]. Moreover, in recent years, the USA and other Western countries have focused on the development of active surveillance systems based on continuous improvement of passive surveillance systems.

3.4 Networked systems have been developed for biosurveillance and early warning

Information systems are an important part of biosurveillance capability, and they are most developed in the USA, where they

are characterized by the combination of national planning and departmental initiative but reveal the problem of redundant construction. In total, by 2005, six federal agencies in the USA had set up 72 information systems for coping with biothreats. Almost all government departments involved with biothreats had developed a variety of information systems, the majority of which were effectively interconnected to form intensive information systems for surveillance and early warning. Further, some other systems are being studied for the main purpose of supporting the federal agencies in preparing for and responding to public health emergencies more effectively and improving capabilities for information exchange and liaison. These include the national environmental public health tracking network (NEPHTN) under the leadership of the US Department of Health and Human Services, the epidemic outbreak surveillance (EOS) system and the biothreats early warning system Bio-ALIRT under the leadership of the US Department of Defense, and the program for response options and technology enhancements for chemical/biological terrorism (PROTECT) under the leadership of the US Department of Energy [8–10].

3.5 The information systems for surveillance and early warning are integrated

In June 2013, the USA issued the *National Biosurveillance Science Technology Roadmap*, which was both the technology implementation plan for the *National Strategy for Biosurveillance* issued in July 2012 and an important strategic action to upgrade and build a new biosurveillance system on the basis of the domestic and global situation [1]. The roadmap summarized existing programs of US federal agencies and departments, and identified subsequent development priorities, such as the national biosurveillance integration system (NBIS), national ecological observatory network (NEON), national animal health monitoring system (NAHMS), global network for monitoring zoonotic pathogens (PREDICT), and, for the Department of Defense, the next generation diagnosis system (NGDS), electronic surveillance system for the early notification of community-based epidemics (ESSENCE), and the "ecological system" project for biodetection. Moreover, this roadmap attempted to overcome the disadvantages of redundant construction and innovatively developed capabilities for integrating and analyzing information and early warning among different systems by focusing on strengthening cooperation among departments, promoting data exchange and fusion, and enhancing capabilities for integrating and processing information and data.

3.6 The central role of the surveillance and early warning platform is realized

Biosurveillance information and data can fulfill its role only after being analyzed. Detection and identification is the antenna of biosurveillance; the transmission system for information and data is the neural network; and processing and application of the data is the nerve center. The surveillance and early warning platform is the most important embodiment of this nerve center, the information center to realize the role of surveillance and early warning, and the essential support to implement emergency management of the biological event. The USA and other Western countries are far ahead in this field, and a variety of management platforms for biosurveillance and early warning systems have been put into use and are being continuously improved, thereby representing the development trend of platforms for biothreat emergency management and comprehensive command. Such systems include HPAC, EpiSimS, BioWar, GLEaMviz, NARAC, ARGOS, and others [11–13]. These platforms, crucial technical equipment with high technological sensitivity, which Western countries will not supply to China, are largely developed under the leadership of the military or security agencies.

In summary, the developed countries, led by the USA, have built advanced national biosurveillance systems that play an important role in managing biothreats by implementing national overall planning, cooperation between the military and civilian authorities, and giving full play to the supporting role of science and technology.

4 Lessons from biosurveillance capability building in developed countries

China's overall biosecurity capability still lags significantly behind that of the developed countries; the aspects showing the greatest gaps include the acquisition, comprehensive analysis, and early warning application of biothreat information. The present situation does not meet China's national security needs. Biosurveillance capability building involves various industry sectors and many scientific and technological challenges, and the complexity of the task, the great demand for funds, and the lengthiness of the process all make it an extremely arduous task. However, we can learn from the experiences in overall deployment and implementation of biosurveillance capability building in the USA and other countries, and thereby promote corresponding efforts to improve the biosurveillance capability of China.

4.1 The precondition is to develop a benign top-level design

Biosurveillance and early warning capability building should be integrated into the overall planning of national biosecurity development. We should constitute an overall management system with a benign top-level design, and quicken development and application of technologies for biodetection, biosurveillance, and early warning applications. We should establish a major science and technology project to select outstanding scientific institutions and manufacturing enterprises that work in collaboration

to form a chain that is beneficial for research, manufacturing, testing, deployment, upgrading, and capability building of the required technologies and products. Moreover, we should quicken development of specific biosurveillance and early warning capability building in China by developing technical standards and specifications and overcoming fragmentation and redundancy in research.

4.2 The key is to implement overall management

We should establish an excellent information sharing mechanism to form an unblocked chain for the collection, transmission, processing, and application of data while increasing the availability of data on the premise that security and secrecy are ensured. We should develop technical standards and specifications and build a "highway" for data sharing to eliminate nonstandard, incomplete, and incompatible data. We should institute a collaboration mechanism between departments to prevent problems such as data islands, data fragmentation, and underuse of available data, and set up a data pool to save costs. Moreover, we should build a comprehensive national platform for biosurveillance and early warning at both the military and civilian levels, depending on the Academy of Military Medical Sciences and the Chinese Center for Disease Control and Prevention, respectively; both platforms should play leading roles in coordination.

4.3 The foundation is to improve the network system

We should implement three-dimensional surveillance strategies and build three-tiered networks for surveillance and early warning consisting of overseas, border, and domestic surveillance. We should attach importance to the dynamic tracking and analysis of overseas biothreats, set up overseas surveillance sentinels, and strengthen international cooperation; we should enhance capability for border surveillance by strengthening epidemic surveillance in border areas and the "guard" role of the customs quarantine system; and we should develop new surveillance systems, further refine the domestic biosurveillance network, and establish data sharing mechanisms between different systems.

4.4 The core is to strengthen scientific and technological innovation

Attention should be paid to the study of technologies for the identification and detection of novel and artificial pathogens. To do this, we should strengthen comprehensive risk evaluation of novel and exotic virulent pathogens, drug-resistant pathogens, genetically modified pathogens, and synthetic and other pathogens and improve our capability to identify and trace novel and unknown biothreats.

Attention should be paid to the study of the dynamics of the occurrence and development of major biosecurity events. To do this, we should carry out studies on the diffusion dynamics and behavior of aerosols of important pathogenic microorganisms in different environments such as vital areas, key cities, and developed areas, thereby building up capability for forecasting biothreat situations.

Attention should be paid to the study of technologies and equipment for rapid onsite detection of harmful organisms to meet the needs of customers in different environments. The technologies and equipment in this field have wide applications and great market potential, which makes them priorities for the biodefense industry.

Attention should be paid to the study of technologies for identification and tracking of harmful organisms. To do this, we should strengthen the study of technologies for identifying molecular markers and tracing the sources of important hazardous organisms based on biological, physical, and chemical methods, with the intention of providing support to source tracing of biothreats and the response to and control of biological events.

Attention should be paid to the study of technologies for real-time biosecurity surveillance. To do this, we should construct an effective background characteristics database, including population characteristics, environmental adaptations, and genetic information of the animals, plants, and microorganisms in important strategic and potential target areas of China. We should strengthen the study of technologies for digitized acquisition, networked transmission, efficient processing, and automated distribution of biothreat early warning information, and develop systems for real-time online surveillance and early warning to improve national security capabilities.

Attention should be paid to the study of technologies for big data mining and information integration related to biosecurity. To do this, we should take advantage of multidisciplinary crossing among various organizations to improve the technologies for integration and conversion, screening and selection, real-time data acquisition, integration and analysis of biosecurity surveillance data, and the collection, mining, and analysis of biosecurity-related big data.

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