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# Epidemic intelligence trinity: Detection, risk assessment, and early warning

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Emerging infectious diseases have been frequently observed. The occurrence of infectious diseases is highly uncertain because of the unpredictability of pathogen, the complexity of occurrence time and site, and the characteristics of transmission. Early detection and immediate implementation of effective interventions within a reasonable time are the keys to preventing pandemics.[1] However, due to the insufficiency of the traditional surveillance and early warning, which relied heavily on passive reporting by healthcare institutions,[2] the early warning time lags behind the risk factor identification, syndrome differentiation (pneumonia of unknown cause), and suspected case confirmation of the infectious disease at the gateway of clustered cases. This paper aimed to face the challenges mentioned above and propose a universal epidemic intelligence model to establish a novel infectious disease surveillance and early warning system based on the trinity of surveillance and detection, risk assessment, and early warning.

Detection refers to multi-source heterogeneous data collection and multi-channel surveillance, which is different from the single channel used in traditional surveillance. The data and information needed for surveillance and detection can be obtained using the epidemiological triangle that encompasses three types of information: Pathogens, hosts, and the environment. During the global coronavirus disease 2019 (COVID-19) pandemic, epidemiological surveys of wastewater based on sewage surveillance had an important role, and the detection of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in sewage sludge preceded the detection of cases.[3] Previous studies have found some transmissible intestinal viruses, such as poliovirus, adenovirus, norovirus, rotavirus, and hepatitis A virus.

Surveillance and detection data can be collected through multi-channel surveillance. Information sources can be divided into risk factors and syndromic information in terms of the data application [Figure 1]. By analyzing the data of active and passive surveillance, the direct or indirect contributing factors of the occurrence and development of the disease, as well as the possible etiological clues, could be identified. For instance, the species, quantity, distribution, and seasonal changes of the vector, which can affect the occurrence and spread of plague, epidemic hemorrhagic fever, malaria, dengue fever, filariasis, influenza, monkeypox, and other infectious diseases, can be regarded as crucial early warning indicators of the disease. Natural disasters such as droughts, floods, tsunamis, and earthquakes could lead to outbreaks of infectious diseases. The spread of respiratory infections may be accelerated in dense populations, especially those with wide mobility and low vaccination rates, thus increasing the risk of outbreaks, especially during major events or holidays.

The time nodes of the index information significantly influence the timely discovery of a disease. Frequently, the extensive use of the combinations of multi-source or multiple data dramatically improves the sensitivity of detecting disease outbreaks. Before a hospital visit, the first node may be the increased risk factors. For instance, the appropriate temperature, rainfall, and other factors increase the number of mosquitoes, before an outbreak of dengue fever. The pathogen may be detected accidentally upon admission to quarantine, physical examination at medical institutions, or by other

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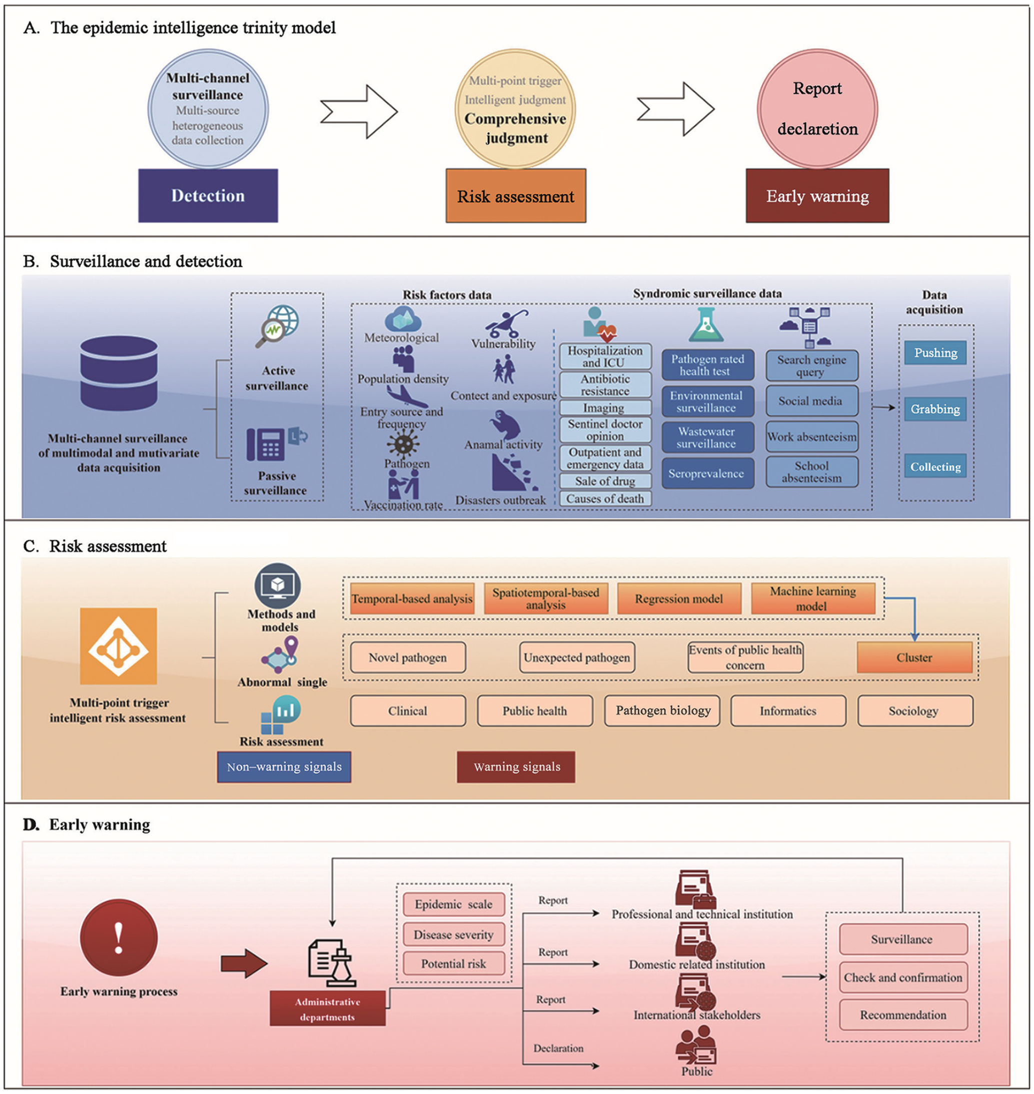


**Figure 1:** Trinity of the infectious disease surveillance and early warning. Conceptual view of the epidemic intelligence trinity. None of the elements were exhausted. (A) The structure of the trinity. (B) Part 1: Surveillance and detection. (C) Part 2: Risk assessment. (D) Part 3: Early warning.

unrelated tests. Prior to visiting the hospital or emergence of clinical symptoms, the infected person could search online and purchase over-the-counter medications. Aggregated absenteeism occurs among students and employees, while the positive results of community sewage pathogen detection are obtained.

Data acquisition methods include grabbing, pushing, and collecting. The acquisition methods should consider not only the surveillance efficiency but also the feasibility under objective conditions. For example, data from public opinion on the internet, doctors' forums, migration information, and demographic information are obtained mainly by grabbing. Data from medical institutions, such as imaging, laboratory, and outpatient and emergency, are obtained mainly by pushing or collecting.

Risk assessment refers to the multi-point triggering of intelligence and comprehensive risk assessments, which differs from the single trigger. Based on surveillance data, identifying unexpected early warning signals of infectious diseases aim to discover and identify the occurrence or development trends of infectious diseases by using a model analysis or the detection of abnormalities such as rare pathogens and novel pathogens according to the judgment of professional institutions and experts.

Based on traditional surveillance techniques, advanced and newly developed modern data analysis techniques should be supplemented. According to the different data characteristics, the anomaly signal analysis methods are basically data-driven models, such as clustering analysis, decision tree analysis, Bayesian network, neural network, deep learning, and other algorithms, which can analyze multi-modal data, including graphic data, natural language information, video, audio, counting and measuring data. In addition, there is a parameter-driven model represented by the infectious disease transmission dynamic model.

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According to the different dimensions of the clustering analysis, clustering early warning models can be categorized into temporal and spatial types. Regarding the different data characteristics, anomaly signal analysis methods include data-driven and parameter-driven models.[4]

The term "early warning" refers to early warning reports and dissemination mechanisms. If an unexpected signal is confirmed to indicate intolerable risk, it is necessary to inform all relevant stakeholders and take immediate prevention and control actions to minimize the health and social hazards.

According to the International Health Regulations in 2005 (IHR 2005), a case of infectious disease with severe public health impacts (such as smallpox, poliomyelitis caused by wild strains, human influenza caused by a new sub-type virus, and severe acute respiratory syndrome [SARS]) or an outbreak of a disease with severe social impacts (such as cholera, pneumonic plague, yellow fever, viral hemorrhagic fever, West Nile fever, or dengue fever) detected by the national surveillance system should be reported to the World Health Organization (WHO) within 24 h.[5]

It would be beneficial if health administrative departments consider issuing early warnings or notifications to professional and technical institutions, the public, and international stakeholders. This could be based on factors such as the scale of the disease occurrence, its severity, risk assessment outcomes, and specific disease characteristics. Therefore, in line with local laws, regulations, and guidelines, early warning information shall be reported to the administrative departments by the discovering person or entity to enable the most rapid joint prevention and control, information communication, coordination of resources, and the formulation of appropriate preventive measures.

Based on the epidemic intelligence trinity, there are five key suggestions as follows: First, surveillance and detection data can be collected through multi-channel surveillance. Sewage surveillance could be incorporated into future surveillance for emerging infectious diseases and serve as a vital channel for active surveillance, especially for intestinal infectious diseases. New surveillance based on earlier nodes should be established, such as medicine purchases, search query data, and work absenteeism. In addition to traditional passive surveillance, a more active surveillance method should be applied. Second, modern techniques to support multi-point triggering should be established. Research and application of modern technologies, such as information technology and mathematical analysis models, are encouraged to supplement traditional surveillance technology. Further, a comprehensive risk assessment of abnormal signs of the disease should be performed by establishing a risk assessment model of infectious diseases according to the disease characteristics and the environment. Third, based on the epidemic intelligence trinity model, information sharing and trust architectures should be considered globally to enable better preparation for future pandemics and epidemics. Countries and regions need to improve surveillance channels within the acceptance of conditions, and advanced approaches could be fully used for pathogen surveillance as the basis of early warning technology. Support and cooperation mechanisms need to be established in countries with unfavorable technical, economic, and social conditions. Fourth, transition mechanisms between the epidemic and non-epidemic periods, such as the preparedness of reserve medical staff training, and Fangcang shelter hospital planning, should be established, along with the trinity model. Infectious diseases do not recognize geopolitical borders, and addressing their challenges requires individuals worldwide to come together and work as one, thereby establishing better preparedness for the next pandemic, better early detection and responses for emerging infectious diseases, and achieving the ultimate goal of public health and population medicine. Fifth, systematic considerations should be taken to achieve integration of the three, inter-connected parts. Detection is the basis of risk assessment provided by multi-source data from multi-channel surveillance information for multi-point triggering of an early warning. Finally, the ultimate goal underlying the provision of timely information to the public as well as relevant international agencies is the enabling of a cooperative and timely response to future outbreaks.

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## Conflicts of interest

None.

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