Methods and Applications

Automatic Warning Practice of Multi-Source Surveillance and Multi-Point Trigger for Infectious Diseases — Yuhang District, Hangzhou City, Zhejiang Province, China, January–April 2024

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ABSTRACT

Introduction: This study presents empirical evidence from the implementation of an automated infectious disease warning system utilizing multi-source surveillance and multi-point triggers in Yuhang District, Hangzhou City, Zhejiang Province, so as to provide reference for more extensive practice of infectious disease surveillance and early warning in the future.

Methods: The data were obtained from the Health Emergency Intelligent Control Platform of Yuhang District from January 1 to April 30, 2024, encompassing warning signal issuance and response documentation. Descriptive epidemiological method was used to analyze the early warning signals.

Results: From January 1 to April 30, 2024, the Health Emergency Intelligent Control Platform in Yuhang District generated 4,598 valid warning signals, with a warning signal positive rate of 36.43%. The early warning system detected 71 infectious disease outbreaks reported through the Intelligent Control Platform, including 24 single-source early warning and 47 multi-source early warning. The sensitivity was 78.02%, demonstrating improved performance compared to existing infectious disease surveillance and warning systems.

Conclusions: This represents the first domestic publication evaluating an automated multi-source surveillance and multi-point trigger warning system. By integrating and correlating multi-source data, the system can efficiently and accurately detect warning signals of infectious disease incidents, which has significant practical implications for early surveillance, warning, and management of infectious diseases.

Infectious diseases remain a persistent global health threat. The increasing impact of emerging and re-emerging infectious diseases in recent years has created unprecedented challenges for disease surveillance and warning systems (*1*). The development of intelligent warning mechanisms incorporating multi-point triggers and multi-channel surveillance represents a crucial advancement in enhancing early detection and warning capabilities for infectious diseases (*2*–*3*).

Building upon theoretical research in intelligent warning system development, Yuhang District has implemented a Health Emergency Intelligent Control Platform. This comprehensive system integrates data management, warning triggers, emergency command operations, and visual analytics capabilities. The platform facilitates sophisticated disease surveillance through multiple data sources, employs diverse analytical models, and implements multi-point warning triggers. Through coordinated command and control mechanisms, the platform enables rapid information dissemination and emergency response deployment.

Yuhang District, situated in northwestern Hangzhou City, Zhejiang Province, encompasses 942 km^2 and comprises 5 towns and 7 sub-districts. As of 2023, the district's population has reached 1.36 million. This study presents an analysis of surveillance and warning outcomes from the Health Emergency Intelligent Control Platform implemented in Yuhang District.

METHODS

Data Sources

The data were obtained from the Health Emergency Intelligent Control Platform of Yuhang District from January 1 to April 30, 2024, encompassing warning signal issuance and response documentation. The multi-source surveillance system integrates three primary data streams: syndromic data from the hospital

information system (HIS) of medical institutions, school illness-related absenteeism records, and infectious disease report cards. The HIS data comprises patient demographics, syndromic presentations, diagnostic information, disease onset timing, and consultation dates. School absenteeism records include student demographics, specific absence justifications, and absence dates. Infectious disease report cards contain case demographics, disease onset timing, diagnostic classifications, reporting timestamps, and reporting institution identifiers.

Warning Process

The platform synthesizes these multi-source data streams through integrated algorithmic models to implement hierarchical surveillance and warning protocols. The system achieves multidimensional warning capabilities by correlating surveillance data across multiple domains, including student enrollment records and elderly care facility resident identification data. The warning mechanism primarily employs fixed-value algorithms for rapid alert generation. Upon warning signal activation, the system automatically notifies the relevant local community health service center. Healthcare staff then process the incident through a dedicated management system, ensuring comprehensive closed-loop operational oversight.

Analysis Indicators and Definitions

This study analyzes warning signal frequencies and their corresponding response outcomes. Signal verification was conducted through data analysis and telephone verification protocols. The following key metrics were evaluated: 1) Positive warning signals, defined as signals that, upon verification, indicated early manifestation of an infectious disease outbreak; 2) Positive warning signal rate, calculated as the percentage of positive warning signals among valid warning signals; and 3) Warning sensitivity, measured as the proportion of actual outbreak incidents successfully identified by the warning system. To validate the warning platform's sensitivity, this study utilized clustered infectious disease incidents reported through the district's intelligent control platform as the reference standard for actual outbreak incidents.

Statistical Analysis

Data organization and analysis were performed using WPS Excel 2016 software (Kingsoft, Beijing, China). Chi-square tests for positive rates were conducted using R software (version 4.4.1; The R Foundation for Statistical Computing, Vienne, Austria), with $P<0.05$ considered statistically significant.

RESULTS

Basic Situation

From January 1 to April 30, 2024, the Health Emergency Intelligent Control Platform in Yuhang District generated 5,944 warning signals. After excluding 1,346 duplicate signals, 4,598 valid warning signals remained, averaging 38 valid signals per day. Following data analysis and telephone verification, 1,184 signals were eliminated, yielding 3,414 preliminary suspected signals. These comprised 2,663 single-source triggers, 318 two-source triggers, and 433 three-source triggers.

Positive Rate of Warning Signals

Investigation confirmed 1,675 positive warning signals, representing 36.43% (1,675/4,598) of valid signals. The positive rates varied by data source: HIS system syndromes at 32.44% (1,367/4,214), illness-related absenteeism at 78.93% (251/318), and infectious disease report cards at 86.36% (57/66). Chi-square analysis revealed statistically significant differences among these three sources ($\chi^2=348.073$, $P<0.001$), as shown in Table 1. Of the 2,923 false positive signals, 2,564 (87.72%) were attributed to angina syndrome, which primarily represented non-communicable conditions such as acute angina and laryngopharyngitis. After excluding these angina syndrome false positives, the HIS system's syndrome warning positive rate increased to 82.85% (1,367/1,650), and the overall valid positive rate reached 82.35% (1,675/2,034). This adjusted analysis showed no statistically significant differences in positive rates among HIS system syndromes, school absenteeism, and infectious disease report cards ($\chi^2=3.571$, $P=0.168$).

Of the 1,675 positive warning signals, HIS system syndromes constituted the majority at 81.61%, with fever respiratory syndromes being predominant (62.69%). Angina syndrome signals accounted for 16.72% (280 signals). School absenteeism due to illness generated 251 positive warning signals (14.99%), primarily from fever symptoms (8.42%). The infectious disease report cards yielded 57 positive warning signals (3.40%), with mumps representing 98.25% (56/57) of these cases (Table 2).

TABLE 1. Results of multi-source surveillance and multi-point trigger warning in Yuhang District, Hangzhou City.

Data source	Number of valid signals	Number of positive signals	Positive rate (%)
HIS system syndromes	4,214	1,367	32.44
School absenteeism due to illness	318	251	78.93
Infectious disease report cards	66	57	86.36
Total	4,598	1,675	36.43

TABLE 2. Composition and positive signals of multi-source surveillance and multi-point trigger early warning.

Warning category		Number of positive signals	Composition ratio (%)
HIS system syndromes	Fever Respiratory	1,050	62.69
	Angina	280	16.72
	Gastroenteritis	21	1.25
	Mumps	15	0.90
	Fever with Rash	1	0.06
	Subtotal	1,367	81.61
School absenteeism due to illness	Fever	141	8.42
	Cough/Sore Throat/Runny Nose	64	3.82
	Fever, Cough/Sore Throat/Runny Nose	40	2.39
	Nausea/Vomiting/Diarrhea	6	0.36
	Subtotal	251	14.99
Infectious disease report cards	Mumps	56	3.34
	Hand-Foot-and-Mouth Disease	1	0.06
	Subtotal	57	3.40
Total		1,675	100.00

Abbreviation: HIS=hospital information system.

Warning Sensitivity

From January to April 2024, the multi-point trigger warning system detected 71 out of 91 infectious disease outbreaks reported through the Intelligent Control Platform, yielding a warning sensitivity of 78.02% (71/91). Multi-source warnings accounted for 66.20% (47 cases) of successful detections, while single-source warnings comprised 33.80% (24 cases). Notably, only 33.80% (24 cases) were detected through infectious disease report cards. Among the 20 undetected incidents, the distribution was: 11 cases of other infectious diarrheal diseases, 5 cases of influenza, and 4 cases of hand-foot-and-mouth disease. Analysis of these missed detections revealed several contributing factors: 11 incidents involved delayed student absenteeism feedback combined with mild symptoms that did not prompt medical visits; 4 incidents had cases dispersed across different classes; 2 incidents lacked complete student enrollment information; 1 incident each was attributed to non-imported infectious disease report card data and treatment at an out-of-jurisdiction medical facility. Additionally, one hand-foot-and-mouth disease incident went undetected due to a warning threshold set above the clustering standard.

DISCUSSION

Analysis of the Yuhang District Health Emergency Intelligent Control Platform's operational data from January to April 2024 demonstrates the effectiveness of its multi-source surveillance and multi-point trigger warning system. The system successfully generated warning signals by integrating data from three primary sources: hospital information system syndromes, infectious disease report cards, and school absenteeism records, with HIS-derived syndromic data serving as the predominant warning trigger.

Our analysis identified 1,346 duplicate warning signals, which were generated sequentially as case numbers increased. While single-source triggers constituted the majority of suspected signals, multi-source triggers were less frequent. This pattern may be attributed to two key factors: first, individuals with mild symptoms often did not seek medical attention,

resulting in incomplete diagnostic data for warning generation; second, gaps in illness-related absenteeism reporting led to missed warning signals from school surveillance data.

The distribution of positive warning signals was predominantly characterized by fever respiratory syndromes, demonstrating this indicator's sensitivity in detecting potential disease transmission risks. However, infectious disease report cards generated relatively few positive signals, limited primarily to mumps and hand-foot-and-mouth disease. This limitation stems from several factors: first, the report cards originate from the China Information System for Disease Control and Prevention (CISDCP), where many cases either lack definitive infectious disease diagnoses or involve non-notifiable conditions; second, the platform has not achieved real-time data integration, requiring manual data transfer from CISDCP; and third, the effectiveness of report card-based warnings depends on accurate diagnosis and standardized reporting practices by healthcare facilities. Consequently, relying solely on infectious disease report cards for warning generation may result in data gaps that compromise the system's sensitivity.

Of the 1,675 warning signals confirmed as early indicators of infectious disease outbreaks, community health service centers implemented timely preventive measures, with only 71 cases requiring on-site management for cluster or outbreak events. The system achieved a valid positive warning rate of 36.43%, which improved to 82.35% after excluding false-positive angina syndrome signals — significantly higher than the China Infectious Diseases Automated-alert and Response System (CIDARS) results in Zhejiang Province from 2014 to 2016 (0.57%) (*4*). After excluding false-positive angina syndrome signals, no statistical differences were observed in positive rates among HIS syndromes, school absenteeism, and infectious disease report cards. Future system optimization will focus on refining angina syndrome criteria to reduce false-positive signals and enhance warning specificity. Notably, the system's sensitivity surpassed the spatiotemporal detection warning results of CIDARS in Zhejiang Province from 2017 to 2021 (66.02%) (*5*). These findings suggest that comprehensive student registration information, combined with integrated multi-source data from absenteeism, medical visits, and disease reports, substantially improves both the positive rate and accuracy of warning signals.

The empirical evidence demonstrates that all 24 single-source warnings originated from infectious disease report cards, while the remaining 47 warnings utilized multiple data sources, including absenteeism records. These findings underscore that multi-point trigger surveillance and warning systems enhance detection sensitivity while reducing omissions caused by human error and procedural inconsistencies (*6*–*7*). Furthermore, the analysis of the 20 undetected incidents highlights critical areas for improvement, including the need for higher-quality surveillance data through comprehensive absenteeism reporting and expanded geographical coverage. Enhancement of warning models, particularly through the integration of fixed-value warnings with model-based approaches, could further optimize warning sensitivity.

The implementation of an automated infectious disease warning system incorporating multi-source surveillance and multi-point triggers enables real-time data integration from critical locations and populations, including medical facilities, educational institutions, and elderly care centers. Through the correlation and integration of diverse data sources, the system efficiently identifies and validates warning signals for infectious disease incidents. This comprehensive approach to warning and incident management encompasses infectious diseases, five syndromic categories, and location-specific surveillance, demonstrating significant practical value for early detection, warning, and disease control measures.

Despite these advances, the platform's multi-source surveillance data coverage remains constrained, primarily relying on syndromic data from healthcare facilities, infectious disease report cards, and school-based symptom surveillance. The platform has not yet achieved complete data integration with infectious disease reporting systems. Additionally, current warning algorithms require further optimization, and the integration of various predictive models needs additional exploration.

Future developments will expand data sources to include pharmacy sales records, laboratory testing data from hospital LIS, nursing home records, and inbound traveler information. Concurrent efforts will focus on optimizing the warning model and enhancing the platform's overall effectiveness.

Conflicts of interest: No conflicts of interest.

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