IAES Journal of Electrical and Electronics Engineering
Vol. 1, No. 2, December 2014, pp. 24~28
ISSN: 2338-7432, DOI: 10.11591/jeee.v1i2.pp24-28

Health informatics for public health surveillance: systems, data integration, and emerging challenges

Tole Sutikno[1], Lina Handayani[2]
[1]Faculty of Industrial Technology, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2]Faculty of Public Health, Universitas Ahmad Dahlan, Yogyakarta, Indonesia

Article Info

Article history:

Received Feb 13, 2014
Revised Jun 16, 2014
Accepted Jul 9, 2014

Keywords:

Data integration
Electronic health records
Health informatics
Interoperability
Public health surveillance
Syndromic surveillance

ABSTRACT

Health informatics plays an increasingly important role in public health surveillance by enabling the systematic collection, integration, analysis, and dissemination of health-related information. This review critically examines the development of surveillance information systems, focusing on their architectures, data sources, integration mechanisms, and practical applications in population health monitoring. Particular attention is given to electronic health records (EHRs), electronic laboratory reporting (ELR), syndromic surveillance, health information exchange (HIE), and administrative health data as complementary sources of surveillance information. The discussion highlights how data integration can improve the timeliness, completeness, and accessibility of information for disease monitoring, outbreak detection, and public health decision-making. However, the effectiveness of these systems remains constrained by interoperability limitations, inconsistent data quality, incomplete population coverage, privacy concerns, and differences in institutional capacity. The review also examines the importance of standardized data exchange, information governance, and sustainable infrastructure in supporting coordinated surveillance activities. Finally, emerging research directions are identified, emphasizing integrated surveillance architectures, improved data quality management, responsible data sharing, and stronger collaboration between healthcare providers and public health agencies.

This is an open access article under the CC BY-SA license.

1. INTRODUCTION

Public health surveillance is essential for monitoring population health, identifying emerging health threats, and supporting timely public health interventions. Traditionally, surveillance activities have relied on routine reporting systems, laboratory notifications, disease registries, and periodic health surveys. However, increasing volumes of electronic health information have created opportunities to improve the timeliness, coverage, and analytical capabilities of surveillance systems.

Health informatics provides the technological and organizational foundation for transforming diverse health information into actionable public health knowledge. It encompasses information systems, data standards, communication infrastructure, data management, and analytical processes that support population-level monitoring. Unlike clinical information systems that primarily support individual patient care, public health surveillance systems must integrate information across individuals, healthcare facilities, geographic areas, and administrative boundaries.

The integration of health information systems also introduces significant technical and organizational challenges. Differences in data formats, terminology, reporting procedures, and institutional responsibilities can prevent information from being exchanged and interpreted consistently. This review examines surveillance system architectures, major data sources, integration strategies, practical applications, and emerging challenges in health informatics for public health surveillance.

2. PUBLIC HEALTH SURVEILLANCE INFORMATION SYSTEMS

Public health surveillance information systems support the continuous collection, analysis, interpretation, and dissemination of health information for public health action. Their primary purpose is to provide reliable information about disease occurrence, health-related events, and population-level trends. The centers for disease control and prevention (CDC) guidelines emphasize that surveillance systems should be evaluated according to attributes such as simplicity, flexibility, data quality, acceptability, sensitivity, predictive value positive, representativeness, timeliness, and stability [1].

Surveillance systems differ according to their objectives, data sources, and operational requirements. Notifiable disease reporting systems collect information about conditions that healthcare providers and laboratories are required to report, while syndromic surveillance systems monitor symptom patterns and related indicators to identify unusual health events. Disease registries, administrative databases, and population health information systems provide additional information for monitoring specific conditions and evaluating public health programs.

The architecture of a surveillance system determines how information is acquired, processed, stored, analyzed, and delivered to public health authorities. Lober *et al.* [2] described essential components of syndromic surveillance architectures, including data acquisition, vocabulary standards, data transport, security, transformation, normalization, and analytical data repositories. These components demonstrate that surveillance is not simply a reporting application, but an interconnected information infrastructure requiring coordination among multiple data providers and users.

3. DATA SOURCES FOR PUBLIC HEALTH SURVEILLANCE

The effectiveness of public health surveillance depends heavily on the availability, quality, and representativeness of its data sources. Conventional sources include case reports, laboratory notifications, hospital records, disease registries, and health surveys. Increasingly, electronic health records (EHRs) and administrative healthcare databases are being used to supplement these established sources and provide more detailed information about population health.

EHRs contain clinical information such as diagnoses, laboratory results, medications, procedures, and patient demographics. These records can support surveillance by identifying disease patterns, monitoring healthcare utilization, and providing additional information about reported cases. Tomines *et al.* [3] discussed the opportunities and barriers associated with using electronic health information for public health activities, emphasizing the need for infrastructure, workforce capacity, and appropriate data-sharing arrangements.

Electronic laboratory reporting (ELR) provides another important source of surveillance information, particularly for infectious and notifiable diseases. Automated laboratory reporting can reduce delays associated with manual reporting and improve the availability of diagnostic information for public health agencies. Egger *et al.* [4] evaluated clinical and administrative data sources for their potential to augment public health surveillance, demonstrating the importance of assessing data sources according to epidemiological characteristics such as representativeness, stability, flexibility, and timeliness.

Syndromic surveillance uses clinical symptoms, chief complaints, and other early indicators to identify unusual patterns that may signal emerging public health events. Unlike confirmed disease reporting, syndromic surveillance can provide early signals before definitive diagnoses become available. Johnson *et al.* [5] discussed recommendations for using inpatient and ambulatory EHR data in syndromic surveillance, illustrating the importance of defining appropriate data elements and operational procedures.

4. DATA INTEGRATION AND INTEROPERABILITY

Data integration is a fundamental requirement for developing comprehensive public health surveillance systems. Health information is distributed across healthcare providers, laboratories, public health agencies, insurance systems, and other organizations, each of which may use different data structures and terminology. Integration mechanisms are therefore needed to collect, transform, harmonize, and exchange information while preserving its meaning and context.

Health information exchange (HIE) provides an important mechanism for sharing electronic health information among independent organizations. It can support automated laboratory reporting, disease notification, and the enrichment of surveillance records with additional clinical information. Dixon *et al.* [6] demonstrated that HIE-based enrichment could improve the completeness of ELR messages, although the quality of information varied across source systems and jurisdictions.

Interoperability involves more than transferring data between information systems. Syntactic interoperability ensures that systems can exchange information using compatible structures, whereas semantic interoperability ensures that the exchanged information has consistent meaning. Dixon *et al.* [7]

reported substantial limitations in the use of standardized vocabularies in ELR messages, highlighting the difficulty of achieving semantic interoperability in operational surveillance environments.

Standardized terminology, data formats, and exchange protocols are consequently important components of integrated surveillance infrastructure. Consistent coding systems and standardized message structures can reduce ambiguity, facilitate automated processing, and improve the comparability of information across institutions. However, technical standards alone cannot guarantee effective integration because data governance, organizational agreements, and consistent implementation are also necessary.

5. APPLICATIONS IN PUBLIC HEALTH MONITORING

Integrated health information systems can support multiple surveillance functions beyond conventional infectious disease reporting. They can facilitate outbreak detection, monitor chronic disease indicators, identify healthcare-associated infections, and evaluate population-level health interventions. These applications demonstrate the potential of health informatics to connect routine healthcare information with broader public health objectives.

For infectious disease surveillance, automated reporting can improve the availability of laboratory results and support timely identification of potential outbreaks. Syndromic surveillance can complement laboratory-confirmed reporting by identifying unusual symptom patterns and changes in healthcare utilization. Combining these sources may provide a more comprehensive understanding of emerging health events, although the reliability of early signals must be assessed before public health action is taken.

Electronic health information can also support monitoring of chronic diseases and health-related risk factors. Clinical records and administrative databases may provide information about diagnoses, preventive services, treatment patterns, and healthcare utilization. Nevertheless, surveillance based on healthcare data primarily reflects individuals who interact with participating healthcare providers and may not accurately represent the entire population.

6. EMERGING CHALLENGES

Data quality remains one of the most important challenges in health informatics for public health surveillance. Incomplete demographic information, inconsistent coding, duplicate records, delayed reporting, and missing clinical details can affect the accuracy of surveillance indicators. Dixon *et al.* [8] examined ELR data and demonstrated that completeness varied across clinical information systems, while data enrichment through HIE could improve selected information fields.

Representativeness is another major concern when surveillance systems depend on electronic healthcare records. Populations with limited access to healthcare services may be underrepresented, potentially producing biased estimates of disease occurrence and health service utilization. Chiolero *et al.* [9] also highlighted the risks of surveillance bias and overdiagnosis when electronic medical records are used without considering the characteristics of the underlying population and healthcare processes.

Privacy, confidentiality, and information security are equally important considerations. Integrated surveillance requires the exchange of potentially sensitive health information among organizations with different responsibilities and access requirements. Appropriate governance mechanisms should therefore define data ownership, authorized use, access control, retention, and accountability while allowing public health agencies to obtain information necessary for legitimate surveillance activities.

Institutional capacity and financial sustainability also influence the success of surveillance systems. Public health agencies may face limitations in technical infrastructure, trained personnel, maintenance resources, and coordination with healthcare providers. Tomines *et al.* [3] emphasized that the availability of electronic health information does not automatically translate into effective public health applications without adequate organizational and workforce support.

7. COMPARATIVE ANALYSIS AND RESEARCH DIRECTIONS

The different surveillance information systems provide complementary capabilities rather than interchangeable solutions. Their suitability depends on the surveillance objective, data availability, reporting requirements, and operational environment [10]. Table 1 summarizes their principal characteristics and limitations.

Table 1. Comparative characteristics of public health surveillance information systems

System or data source	Main function	Major strengths	Main limitations
Notifiable disease reporting	Monitoring legally reportable diseases	Established reporting procedures and defined conditions	Reporting delays and incomplete case information
ELR	Automated notification of laboratory results	Timely diagnostic information and reduced manual reporting	Variable data completeness and terminology
EHRs	Clinical and population health monitoring	Detailed clinical information and multiple data elements	Incomplete population coverage and inconsistent records
Syndromic surveillance	Early detection of unusual health events	Potentially rapid identification of emerging patterns	False alerts and limited diagnostic specificity
HIE	Information sharing across organizations	Improved data accessibility and potential enrichment	Interoperability, governance, and implementation barriers
Disease registries and administrative databases	Longitudinal and condition-specific monitoring	Structured information for trend analysis	Limited scope and possible selection bias

The comparison indicates that effective surveillance requires coordinated use of multiple information sources. Laboratory data can provide diagnostic evidence, EHRs can supply clinical context, and syndromic systems can identify early signals before confirmation. Integrating these sources can improve surveillance capabilities, but the resulting information must be assessed for quality, duplication, and representativeness.

Future research should prioritize interoperable surveillance architectures that support standardized data exchange across clinical and public health environments. Data quality management should be incorporated into the entire information lifecycle, including data capture, validation, transformation, integration, and analysis. Further research is also needed to evaluate the operational value of integrated systems, particularly their effects on detection timeliness, reporting completeness, resource requirements, and public health decision-making.

Another important direction is the development of sustainable governance and institutional collaboration. Effective surveillance depends on clear responsibilities, appropriate privacy safeguards, adequate workforce skills, and long-term financial support. These organizational requirements should be considered alongside technical development to ensure that surveillance systems remain useful and reliable in routine public health practice.

8. CONCLUSION

Health informatics provides an essential foundation for modern public health surveillance by enabling the collection, integration, analysis, and exchange of health information across multiple organizations. EHRs, laboratory reporting, syndromic surveillance, HIE, and administrative databases offer complementary capabilities for monitoring population health and identifying emerging health threats. However, their effectiveness depends on data quality, interoperability, representativeness, privacy protection, and institutional capacity. The review highlights that integrated surveillance should be approached as both a technological and organizational undertaking. Future research should emphasize interoperable architectures, standardized information exchange, systematic data quality management, and sustainable governance arrangements. These developments are important for transforming distributed health information into timely, reliable, and actionable evidence for public health decision-making.

REFERENCES

[1] R. R. German, L. M. Lee, J. M. Horan, R. L. Milstein, C. A. Pertowski, and M. N. Waller, "Updated guidelines for evaluating public health surveillance systems: recommendations from the guidelines working group.," *MMWR. Recommendations and reports : Morbidity and mortality weekly report. Recommendations and reports*, vol. 50, no. RR-13, pp. 1–35; quiz CE1-7, 2001.

[2] W. B. Lober, L. Trigg, and B. Karras, "Information system architectures for syndromic surveillance.," *MMWR supplements*, vol. 53, pp. 203–8, 2004.

[3] A. Tomines, H. Readhead, A. Readhead, and S. Teutsch, "Applications of electronic health information in public health: Uses, opportunities and barriers," *eGEMs (Generating Evidence & Methods to improve patient outcomes)*, vol. 1, no. 2, p. 5, Oct. 2013, doi: 10.13063/2327-9214.1019.

[4] J. R. Egger *et al.*, "Evaluation of clinical and administrative data to augment public health surveillance," *Online Journal of Public Health Informatics*, vol. 5, no. 1, p. e61139, Mar. 2013, doi: 10.5210/ojphi.v5i1.4474.

[5] G. Johnson, C. Ishikawa, R. Zwickl, M. Minami, T. Kass-Hout, and L. Streichert, "Recommendations for syndromic surveillance using inpatient and ambulatory EHR data," *Online Journal of Public Health Informatics*, vol. 5, no. 1, p. e61142, Mar. 2013, doi: 10.5210/ojphi.v5i1.4477.

[6] B. E. Dixon, J. A. Siegel, T. V. Oemig, and S. J. Grannis, "Electronic health information quality challenges and interventions to improve public health surveillance data and practice," *Public Health Reports*, vol. 128, no. 6, pp. 546–553, Nov. 2013, doi: 10.1177/003335491312800614.
[7] B. E. Dixon, J. A. Siegel, T. V. Oemig, and S. J. Grannis, "Towards interoperability for public health surveillance: Experiences from two states," *Online Journal of Public Health Informatics*, vol. 5, no. 1, p. e61070, Mar. 2013, doi: 10.5210/ojphi.v5i1.4395.
[8] B. E. Dixon, S. J. Grannis, and D. Revere, "Measuring the impact of a health information exchange intervention on provider-based notifiable disease reporting using mixed methods: A study protocol," *BMC Medical Informatics and Decision Making*, vol. 13, no. 1, p. 121, Dec. 2013, doi: 10.1186/1472-6947-13-121.
[9] A. Chiolero, V. Santschi, and F. Paccaud, "Public health surveillance with electronic medical records: At risk of surveillance bias and overdiagnosis," *European Journal of Public Health*, vol. 23, no. 3, pp. 350–351, Jun. 2013, doi: 10.1093/eurpub/ckt044.
[10] W. B. Lober, A. Baer, B. T. Karras, and J. S. Duchin, "Collection and Integration of Clinical Data for Surveillance," *Studies in Health Technology and Informatics*, vol. 107, pp. 1211–1215, 2004, doi: 10.3233/978-1-60750-949-3-1211.