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CASE REPORT

Developing an integrated syndromic surveillance application for infectious diseases in New York City

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Abstract

The New York City Health + Hospitals' initiative to develop a comprehensive infectious disease syndromic surveillance application marks a transformative step in healthcare and public health informatics, particularly following the COVID-19 pandemic, which demonstrated the need for swift detection and action against infectious disease threats. This article describes the collaborative efforts and methods employed to construct this initial surveillance system. The application is uniquely designed to amalgamate chief complaints with ancillary data points, such as travel history, to offer a nuanced view of potential outbreaks. The system is integrated with the enterprise electronic health record through automated extraction and transformation workflows, and it delivers interactive analytics through Tableau dashboards. We describe the implementation of this system for monitoring four syndromes, influenza-like illness, gastroenteritis, infectious rash, and asthma, and discuss the impact of these insights on healthcare and public health response and leadership decision-making.

Keywords: Syndromic surveillance; Infectious disease epidemiology; Public health informatics; Healthcare informatics; Electronic health records; Early warning systems

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1. Introduction

The importance of effective syndromic surveillance within healthcare delivery has been underscored by recent global health crises, such as the COVID-19 and mpox pandemics, highlighting the urgent need for early detection systems that can proactively identify and contain the spread of infectious diseases.[1] The New York City Health + Hospitals (NYC H+H) syndromic surveillance application exemplifies an innovative convergence of clinical data analysis and public health intelligence. This effort aligns with the syndromic surveillance principles established by the Centers for Disease Control and Prevention's (CDC) Influenza-Like Illness (ILI)-net system, which has been vital in tracking ILIs and other respiratory conditions.[2] Given New York City's status as a global travel hub and its highly diverse, densely populated communities, the risk of infectious disease transmission is elevated. The NYC H+H application is multi-purpose and leverages data from initial patient screenings, combining syndrome presentation with travel history across all NYC H+H locations in the five boroughs. Since NYC H+H operates on a single enterprise electronic health record (EHR) instance, the same extraction logic and governance-approved syndrome definitions are applied uniformly across the health system; however, this surveillance application reflects NYC H+H facilities only and is not representative of all healthcare systems citywide. This paper outlines the collaborative development of the application and emphasizes the critical role of integrated data systems in enabling early warning and rapid healthcare response.

2. System development and implementation

In an era marked by the rapid emergence of infectious diseases[3], real-time surveillance tools are critical for early detection and response to potential outbreaks within urban healthcare systems. The NYC H+H syndromic surveillance dashboard was developed through a collaborative effort between the System-wide Special Pathogens Program and the healthcare system's data and analytics team, integrating expertise in infectious diseases, epidemiology, health informatics, and data science. The application used EHR data, including chief complaints, International Classification of Diseases, 10th Revision (ICD-10) codes, and travel histories, to track four key syndromes: ILI, gastroenteritis, infectious rash, and asthma. Each syndrome was defined using historical data and clinical criteria, with algorithms designed to extract relevant structured and semi-structured data from the EHR. In the current production implementation, syndrome identification uses a rule-based approach combining (i) ICD-10 diagnosis codes and encounter reason fields and (ii) deterministic, structured query language (SQL)-based wildcard string matching on standardized chief-complaint text (i.e., not advanced natural language processing [NLP]). These data were transformed and visualized through interactive dashboards built in Tableau, allowing users to filter by variables such as timeframe, facility, age, gender, and patient class. Features such as trend analysis, geospatial insights, cross-syndrome comparisons, and automated alerts enable near-real-time monitoring. Extensive data validation, including integration testing, system and unit testing, and user acceptance testing, ensured the accuracy, functionality, and security of the data pipeline. By integrating travel data and leveraging dynamic visualizations, the application provides a robust platform for early detection of infectious disease trends and supports timely, data-driven interventions across the health system.

3. System architecture and electronic health record integration

The application is directly integrated with the enterprise EHR via automated extract–transform–load workflows. Source data are pulled from the EHR reporting layer (e.g., encounter tables, diagnosis tables, chief-complaint fields, and travel screening documentation) into a governed analytic dataset. The Tableau dashboards are published to a secure Tableau Server environment and refresh on a scheduled cadence to support near-real-time operational monitoring (generally within hours of encounter documentation, depending on upstream documentation and reporting-layer availability). Importantly, while the data pipeline is integrated with the EHR, the user-facing analytic interface is delivered in Tableau rather than embedded as a native EHR activity/screen.

4. Data integration and processing

The application pulls from EHRs, including chief complaints, ICD-10 codes, and travel histories. Key processes include:

(i) Syndrome identification: Four key syndromes—ILI, gastroenteritis, infectious rash, and asthma—are defined using historical data and literature.
(ii) Algorithm development: Relevant EHR data are extracted for each syndrome.
(iii) Travel data integration: Travel screening data are merged with symptom records.
(iv) Visualization: Tableau dashboards are developed for real-time trend analysis.
(v) Validation: Integration, system, and user acceptance testing are used for validation.

To improve reproducibility, we further specify the extraction and transformation approach below:

- Extraction layer: SQL views query encounter-level records and join diagnoses, chief complaints, and travel screening elements using encounter identifiers and timestamps.
- Standardization layer: Free-text fields used in matching are case-normalized, and common punctuation/spacing artifacts are removed to reduce documentation variability; categorical fields (facility, borough, patient class) are mapped to controlled vocabularies.
- Syndrome flagging layer: Encounters are flagged when they meet ICD-10 criteria and/or keyword criteria

(chief complaint/encounter reason), optionally stratified using travel screening results.

- De-duplication: Encounters are counted once per syndrome per visit to avoid double-counting when multiple matching terms exist in the same record.
- Governance: Syndrome definitions, keyword lists, ICD-10 groupers, and changes to transformation logic undergo clinical subject matter expert (SME) review and data governance approval prior to deployment.

5. Defining syndromes

Chief complaints represent the initial context and essential information about the problem the patient is experiencing. Although they offer a concise description of the problem, associating chief complaints with defined syndromes can be difficult due to the lack of accuracy and linguistic variations in descriptions. Diagnostic codes, such as ICD-10 codes, capture and catalog keywords, symptoms, complaints, and other metrics and can be used to query the EHR system to find and track defined syndromes. For our application, we used both chief complaints and ICD-10 codes to extract data for the four syndromes below:

(i) ILI: This component of the application tracks ILI symptom trends, correlating them with travel history and known exposures. It models the CDC's ILI-net approach by monitoring respiratory illness symptoms that are not necessarily confirmed as influenza, thereby capturing a broader range of respiratory pathogens.

(ii) Gastroenteritis: Recognizing the varied etiology of gastroenteritis, the application incorporates chief complaints of fever, diarrhea, and abdominal pain, analyzing them alongside travel history and exposure to identify potential foodborne or waterborne outbreaks.

(iii) Infectious rash: The rash surveillance component integrates clinical presentations with fever, travel, and exposure data. It aims to identify emerging outbreaks of diseases characterized by rashes, such as measles or varicella.

(iv) Asthma: While primarily a chronic condition, asthma exacerbations can be linked to infectious diseases, particularly viral respiratory infections. Monitoring asthma-related symptoms provides indirect surveillance of respiratory pathogen activity in the community.

Because chief complaints are frequently entered as short free-text strings, the current implementation applies deterministic, SQL-based string matching (e.g., LIKE wildcard matches) against a curated list of syndrome terms and common variants (including misspellings and colloquial phrasing). This approach can be considered "fuzzy" only in the sense that wildcard patterns can match partial strings; however, it is not a true NLP pipeline (i.e., it does not include tokenization, named entity recognition, or contextual embeddings). Accordingly, ICD-10 logic is used as an additional structured signal to improve reliability, and NLP is planned as a future enhancement.

Once each syndrome was defined, specific data entered in the EHR by clinicians were extracted, transformed, loaded, and displayed into an analytical database (Tableau). Data were extracted from the EHR using ICD codes, physician notes, and various EHR flowsheets (**Table 1**). Extraction and transformation were executed against the NYC H+H enterprise EHR dataset, enabling uniform system-wide surveillance across all NYC H+H facilities. Data for each syndrome were compiled into a dashboard with a variety of filters, such as timeframe (by month), location (facility-specific), associated travel (country-specific), age, gender, and patient class (inpatient, outpatient, and emergency visit).[4] The dashboards displayed monthly count, two-month rolling averages, median counts, and associated trend lines. Data validation techniques, such as integration testing, system testing, unit testing, and user acceptance testing, were used to ensure adequate data quality. Integration testing was carried out to confirm that source data were accurately loaded into the analytical dataset and to verify key parameters and data mappings. In addition, through system and unit testing, we ensured the quality, functionality, performance, and security of the data. This involved checking the integrity and accuracy of the data. Finally, the end users performed user acceptance testing to validate the data and confirm the accuracy of the Tableau dashboard.

We further clarified the transformation steps used to standardize data across facilities:

- Text standardization: Chief-complaint strings were normalized (case normalization; removal of select punctuation) prior to keyword matching to reduce false negatives caused by documentation variation.
- Time standardization: Encounter timestamps were transformed into consistent analytic time grains (daily/weekly/monthly) used by the dashboard filters and trendlines.
- Facility and patient-class standardization: Facility identifiers and patient-class values were mapped to governed categories to ensure consistent roll-ups across the five boroughs.
- Syndrome criteria standardization: ICD-10 code lists and keyword lists were version-controlled; updates were reviewed by clinical SMEs and implemented via governed change control.

Table 1 provides detailed syndrome definitions based on screening criteria and associated diagnosis codes. Chief complaints and ICD-10 codes were used to extract relevant data. Chief-complaint matching was implemented using standardized text and SQL wildcard matching against the curated term lists shown above.

6. Data visualization

The syndromic surveillance application leverages advanced data visualization tools to provide users with a comprehensive and interactive interface. Dashboards are built in Tableau to display a wide range of metrics, including syndromic trends, patient demographics, and geographic distributions. Key features include:

- Dynamic filtering: Users can filter data by timeframes (daily, weekly, monthly), locations (specific facilities or boroughs), and patient demographics (age, gender, and patient class).
- Trend analysis: Rolling averages, median counts, and associated trendlines are plotted for each syndrome, enabling users to identify patterns over time.
- Geospatial insights: Syndromic data are visualized geographically (i.e., by facility), highlighting hotspots of disease activity across New York City (NYC). This facilitates targeted interventions and resource allocation.
- Real-time updates: Dashboards are updated with near-real-time data from EHRs, allowing for continuous monitoring and rapid detection of deviations from expected trends.
- Interactive alerts: Automated threshold-based alerts notify users of significant anomalies, such as a sudden spike in cases of a specific syndrome within a given timeframe or location.
- Cross-syndrome analysis: Visualizations provide insights into overlapping syndromic presentations, helping identify multi-syndrome trends or unusual co-occurrences that could indicate emerging threats.

These tools empower healthcare leaders to gain actionable insights quickly, enhancing situational awareness and response capabilities.

7. Application impact

The implementation of the syndromic surveillance application has already yielded several critical benefits:

- Enhanced early detection: The system's ability to integrate chief complaints with travel history and demographic data has improved the identification of disease clusters, including emerging conditions not previously seen in NYC. For example, an increase in rash complaints on the Syndromic Surveillance Dashboard corresponded to the increase in mpox cases in the summer of 2022.
- Data-driven decision-making: Leadership has been able to inform certain NYC H+H facilities that were experiencing increasing cases of respiratory syncytial virus, COVID-19, and/or influenza during the fall and winter of 2023 "tripledemic," thereby supporting more targeted screening.[5,6]

8. Discussion

The 21st century has seen a series of infectious disease challenges, including the COVID-19 and mpox pandemics, that have tested the resilience of public health

Table 1. Syndrome definitions and associated International Classification of Diseases, 10th Revision codes

Syndrome	Definition (screening criteria + encounter reason/chief complaint)		Diagnosis code
Gastroenteritis	Diarrhea + one or more of the following or diagnosis code Travel + fever + one or more of the following	Diarrhea, enteritis, gastroenteritis, loose stools, stomach flu, throwing up, vomit	R19.7, A09, R11
Influenza-like illness	Fever + one or more of the following or diagnosis code Travel + fever + one or more of the following	Bronchitis, chest cold, chest congestion, chest pain, cough, breathing problem, difficulty breathing, pneumonia, shortness of breath, upper respiratory infection, flu, influenza, fever, sore throat	J24.0, R05, J12-J18, R06.02, J04.2, J06
Asthma	Asthma + one or more of the following or diagnosis code Travel + fever + one or more of the following	Asthma, wheezing, reactive airway	J45, R06.2
Infectious rash	Fever + rash or diagnosis code Travel + fever + rash + one or more of the following	Rash	R21, R23

systems globally and underlined the role of early warning systems in detecting and controlling such outbreaks.[7,8] In response to this need for rapid, actionable data, NYC H+H spearheaded the development of an infectious disease syndromic surveillance application that could enable quick recognition and response to emerging threats. We reflect on the lessons learned from prior outbreaks, particularly the COVID-19 pandemic, and how they informed the development of this surveillance system.

Syndromic surveillance has evolved toward automated, near-real-time platforms that integrate routinely collected clinical data for early situational awareness. Established approaches include large-scale platforms that support detection and monitoring across a wide range of conditions and operational contexts (e.g., national syndromic services) and emergency department-based implementations that validate syndrome definitions using combinations of diagnosis codes and presenting complaints and compare trends to external reference data.[9–11] More recent studies have emphasized the expanding role of EHR-derived surveillance for both routine monitoring and emergency response, including COVID-19-era operational decision support and the need for consistent governance, data quality management, and dashboard interpretability.[10,11] Within this landscape, the NYC H+H implementation is distinctive in (i) enterprise-wide deployment across the nation's largest municipal health system operating on a single EHR, (ii) explicit linkage of syndromic signals to travel screening workflows to support early identification of imported or travel-associated threats, and (iii) operationalization for healthcare leadership decisions (e.g., targeted screening, resource planning) rather than solely retrospective epidemiologic reporting.

The recent COVID-19 pandemic has been a stark reminder of the essential need for robust infectious disease surveillance. The rapid and often silent spread of severe acute respiratory syndrome coronavirus 2 emphasized the gaps in traditional surveillance mechanisms, particularly in their ability to detect early transmission. This experience provided valuable insights into enhancing syndromic surveillance systems to better capture the breadth of clinical presentations and the subtleties of infectious disease spread. Key lessons include:

- Data integration is key: Combining multiple data streams, such as travel history and diagnostic imaging trends, enhances the granularity of surveillance.
- Collaboration drives innovation: The system was developed through interdisciplinary partnerships, underscoring the importance of diverse expertise in public health informatics. From project initiation through pilot testing, we held recurring joint planning sessions that included infectious disease clinicians, leaders in epidemiology and special pathogens, data governance stakeholders, and analytics/reporting developers. A key outcome of this collaboration was the development of a shared data model and governed syndrome logic: data analysts and clinical SMEs iteratively refined the ICD-10 groupers and keyword lists to ensure that extracted variables were clinically meaningful (not solely technically convenient).
- Standardization challenges: Variability in how symptoms were recorded in EHRs could limit the system's accuracy. Future iterations should incorporate NLP to parse unstructured clinical notes.

9. Validation and quality assurance

A multi-layer validation approach was used to ensure accuracy, reliability, performance, and security:

- Integration testing: Reconciled record counts and key aggregates between the EHR reporting layer and the analytic dataset (e.g., encounter counts by facility/time period), verified join integrity (encounter IDs, timestamps), and monitored data completeness (e.g., null rates for key fields). Primary metrics included record-count concordance, error rates in joins, and completeness thresholds for required fields.
- Unit testing: Validated discrete transformation components (e.g., syndrome flag logic, ICD-10 grouper membership, keyword-list matching) using test cases with known expected outputs. Metrics included test coverage of transformation rules and defect density during development iterations.
- System testing: Assessed end-to-end workflow performance, including refresh success/failure rates, timeliness/latency from encounter documentation to dashboard availability, Tableau load performance for typical filters, and security controls (role-based access, least-privilege permissions). Metrics included refresh success rate, latency checks, and dashboard responsiveness under expected concurrency.
- User acceptance testing: Clinical SMEs reviewed predefined test cases and performed structured joint review sessions comparing dashboard-flagged encounters to EHR chart context for clinical face validity and relevance. Acceptance criteria included concordance of sampled encounters with intended syndrome definitions, interpretability of trends, and operational readiness for leadership workflows. Feedback was documented and used to refine rules and visual displays prior to go-live.

10. Limitations and challenges

While the application represents significant progress, certain limitations persist:

- Non-specificity: Syndromic trends, while valuable, may not always indicate an outbreak. For example, increases in asthma-related symptoms could be linked to environmental factors rather than infectious diseases.
- Scalability: While tailored for NYC, adapting the application for use in smaller healthcare systems or rural areas may require significant modifications.
- Additional data integration: Travel screening data, diagnoses of reportable diseases, and trends in radiographic imaging orders are additional layers of data that may be integrated into the application. These could provide a more comprehensive view of the health landscape and help identify unusual patterns that may indicate an outbreak.
- Free-text variability and rule-based matching constraints: Because the current implementation uses deterministic keyword matching (not advanced NLP), sensitivity may be reduced when documentation is ambiguous, abbreviated, or highly variable across clinicians and sites. This reinforces the need for ongoing governance, periodic review of the keyword list, and planned NLP enhancements to improve generalizability and reduce documentation bias.

11. Recommendations for healthcare leadership

By integrating diverse data streams, such as chief complaints and travel history, the application provides a granular view of syndromic trends, aiding early detection of infectious threats. In addition, the application enables near-real-time monitoring and analysis of data points critical to identifying potential outbreaks and facilitates an agile response to emerging health threats, allowing for quick mobilization of resources, informing healthcare strategies, and enabling healthcare leaders to make rapid, informed decisions. We share potential healthcare strategies that can be taken by healthcare leaders through the 5'S approach: staffing, space, supplies, system, and situational awareness (Table 2).

Table 2. Potential action items for healthcare leaders

5'S	Action
Staffing	Recruit and train rapid response teams: Develop specialized teams trained in infectious disease management and rapid response protocols. Enhance staff flexibility: Cross-train staff to perform multiple roles, enabling a more dynamic response to varying demands. Implement staffing analytics: Use data analytics to forecast staffing needs and optimize staff allocation based on emerging trends in infectious threats.
Space	Expand isolation areas: Increase the number of isolation rooms or areas to accommodate patients with infectious diseases. Modular space solutions: Utilize modular or convertible spaces that can be quickly adapted for different healthcare needs during an outbreak. Optimize patient flow: Implement protocols for efficient patient flow to minimize infection spread and maximize space utilization.
Supplies	Stockpile essential supplies: Maintain a reserve of essential medical supplies and personal protective equipment. Develop supply chain partnerships: Establish partnerships with suppliers for rapid procurement and replenishment of supplies. Implement inventory management systems: Use technology to monitor supply levels and predict future needs based on data trends.
System	Develop decision support tools and patient screening protocols: Implement advanced tools and protocols for patient screening and early recognition. Enhance communication systems: Strengthen internal and external communication channels for efficient dissemination of information and coordination.
Situational awareness	Implement real-time monitoring: Utilize the application for ongoing monitoring of syndromic trends and potential outbreak signals. Conduct regular risk assessments: Regularly evaluate the potential risks and prepare response strategies accordingly. Engage in community awareness programs: Educate and engage with the community to enhance awareness and preparedness for infectious threats.

12. Conclusion

NYC H+H's infectious disease syndromic surveillance application exemplifies how data-driven tools can transform healthcare delivery and disease preparedness strategies. The development of such an application represents a significant leap forward in healthcare and public health surveillance by providing an early warning system that integrates diverse data streams. This initiative demonstrates the critical role of interdisciplinary collaboration in developing innovative solutions to complex health challenges. Future research should focus on refining the system's predictive analytics capabilities and expanding the range of syndromes monitored to encompass emerging health threats.

There are limitations inherent in all syndromic surveillance systems. First, the system itself is only as good as the coding data available from the EHR; if information is recorded as free text in EHRs, it cannot be picked up by the syndromic surveillance system when it pulls information using ICD codes.[12,13] In our current implementation, we partially mitigate this limitation by combining ICD-10 logic with rule-based keyword matching of chief complaints; however, improving capture of nuanced free-text documentation remains a priority for future enhancement. One way to potentially mitigate this in the future is to use artificial intelligence in conjunction with syndromic surveillance systems[14], as this may enable the system to incorporate free-text comments in addition to information coded within the EHR. Second, syndromic surveillance is inherently non-specific.[15] For example, there are numerous illnesses associated with respiratory symptoms, many of which are not infectious in nature. However, an uptick in a particular cluster of symptoms can still serve as an early signal for public health authorities and is useful to investigate, even if an outbreak is not the cause. Finally, a syndromic surveillance system must be continually refined to ensure it is accurately capturing data of interest.

Despite these limitations, our syndromic surveillance system can serve as a model for other healthcare delivery systems seeking to enhance their disease surveillance capabilities by leveraging a multidisciplinary approach to data analysis, integrating a wealth of clinical information to provide an early warning system against infectious diseases. The platform can not only contribute to the immediate health system's responsiveness but also add to the broader network of public health surveillance, enriching the data that guide national and international responses to infectious disease threats.

While challenges remain, including the need for better integration of unstructured clinical data and enhanced specificity, the application has already demonstrated its value in improving healthcare delivery and public health preparedness. Future advancements should focus on:

(i) Expanding syndrome coverage: Include additional syndromes to address emerging threats.
(ii) Incorporating artificial intelligence: Leverage artificial intelligence and machine learning to refine predictive capabilities and analyze free-text clinical notes.[16]
(iii) Adapting for broader use: Tailor the application for use in diverse healthcare settings, including smaller systems and rural areas.[17,18]
(iv) Enhancing text analytics: Implement clinically governed NLP to improve robustness to documentation variability, reduce false positives/negatives, and support more portable syndrome definitions across settings.[15–18]

Ultimately, this initiative underscores the critical role of innovation, collaboration, and data-driven decision-making in safeguarding public health. The lessons learned and successes achieved through this effort can serve as a blueprint for other healthcare systems worldwide seeking to enhance their surveillance and response capabilities.

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Conflict of interest

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