

Automated Mortality Surveillance in South-Eastern Ontario for Pandemic Influenza Preparedness

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ABSTRACT

Background: The recent Canadian experience with pandemic H1N1 (pH1N1) influenza in 2009 highlighted the need for enhanced surveillance at local and regional levels to support evidence-based decision making by physicians and public health. We describe the rationale, methodology, and provide preliminary findings from the implementation of an automated Mortality Surveillance System (MSS) in the Kingston, Frontenac and Lennox & Addington (KFL&A) health unit.

Methods: The MSS utilized an automated web-based framework with secure data transfer. A data sharing agreement between the local Medical Officer of Health and the City of Kingston facilitated weekly updates of mortality data. Deaths due to influenza were classified using keywords in the cause of death and a phonetic algorithm to capture alternate spellings. Anomaly detection was modeled on the modified cumulative sum algorithm implemented in the Early Aberration Reporting System.

Results: Retrospective analysis of municipal mortality data over a 10-year period established baseline mortality rates in the region. MSS data monitored during the pH1N1 influenza season showed no significant impact on the burden or timing of mortality in the KFL&A health unit.

Conclusion: Municipal data enabled surveillance of mortality in the KFL&A region with weekly updates. Other municipalities may participate in this surveillance project using the Kingston model without significant ongoing investment. Efforts to improve data quality at the physician and transcription level are ongoing. Integration of mortality data and other real-time data streams into an integrated electronic public health dashboard could provide decision-makers with timely information during public health emergencies.

Key words: Pandemics; emergency preparedness; public health surveillance; excess mortality

La traduction du résumé se trouve à la fin de l'article.

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The measurement of mortality is a basic element in the collection of vital statistics by municipal and provincial governments in Canada. Cause-specific mortality statistics are a valuable marker for the severity of diseases such as influenza. However, this information does not become available from provincial or national databases in a timely fashion to support a public health response. Modern electronic information systems make it possible to share data in near-real time. Mortality data are currently being used in other jurisdictions to monitor possible incidents of bioterrorism, to survey the health effects of climate change, and to assess the severity of disease outbreaks.¹⁻³

The recent Canadian experience with pandemic H1N1 influenza in 2009 highlighted the need for enhanced surveillance at local and regional levels to support evidence-based decision making by physicians and public health.⁴ Surveillance may provide evidence for appropriate reallocation of scarce health resources, targeted interventions for high-risk populations, and valuable public reassurance by public health officials. Public health measures initiated as a result of surveillance may also include public education campaigns, travel restriction recommendations, and social distancing measures to slow the spread of disease.^{5,6}

Death registrations in Ontario

Following death in Ontario, the physician or coroner completes a medical certificate of death. This document includes the immedi-

ate cause of death, as well as antecedent causes and co-morbidities. Deaths requiring coroner investigation may not list a cause pending results of further investigation. Deaths are officially registered when funeral directors submit the medical certificate to the registering municipality office. Under the Vital Statistics Act, municipalities are required to store mortality information in an index and forward the original documentation to the Ontario Office of the Registrar General. When death occurs in one municipal division, but burial and registration occurs in another, the original municipality receives notice from the registering municipality (B. Johnson, personal communication, July 27, 2010).

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Conflict of Interest: None to declare.

Automated mortality surveillance in south-eastern Ontario

This paper describes the implementation of an automated mortality surveillance system by the Kingston, Frontenac and Lennox & Addington public health unit (KFL&A, 2006 census population 191,203) in partnership with the City of Kingston, Ontario (2006 census population 117,207). The Mortality Surveillance System (MSS) utilizes City of Kingston vital statistics data updated weekly for continuous surveillance of all-cause and cause-specific mortality, including influenza. The surveillance model shown in Figure 1 is based upon a framework described by the Centers for Disease Control and Prevention.⁷ The MSS went online in September 2009, and to our knowledge, there is no comparable system in Canada.

In addition to the MSS, the KFL&A health unit uses an acute care syndromic surveillance system that captures real-time data from its three hospitals, which includes Kingston General Hospital, a tertiary care centre serving approximately 500,000 people across South-Eastern Ontario. The acute care surveillance system also captures over 40 hospitals within 12 health units across Ontario. Collected data include emergency visits, admissions, and positive febrile respiratory illness screening results.^{8,9}

A retrospective analysis of 10 years of mortality data was performed to evaluate the validity of the mortality dataset, to establish baseline mortality rates in the Kingston area, and to serve as a foundation for prospective validation during future pandemic outbreaks. The methodology for system implementation, dataset considerations, and a brief analysis of the influenza-related mortality burden on this region are also described.

METHODS

Mortality Surveillance System (MSS) description

The MSS consists of a Java-based web application utilizing an Oracle database, hosted on a secure server administered by the KFL&A health unit. Shown in Figure 2, the data processing, classification and statistical analysis steps following data transfer have been automated and are executed on a regular schedule. The Kingston City Clerk spends fewer than five minutes per week to electronically collate and transmit the municipal mortality records. At the health unit, a staff epidemiologist spends approximately 30 minutes per week to review recent mortality activity. A browser-based graphical interface shown in Figure 3 allows access to the data through pre-defined syndromes or a free-text search. Data can be plotted on a weekly or monthly basis within a definable date range against a historical baseline. The output from an anomaly detection algorithm such as a cumulative sum (CUSUM) can also be displayed as a separate data series.

Figure 1. A surveillance model for early outbreak detection, as adapted from the Centers for Disease Control and Prevention⁷

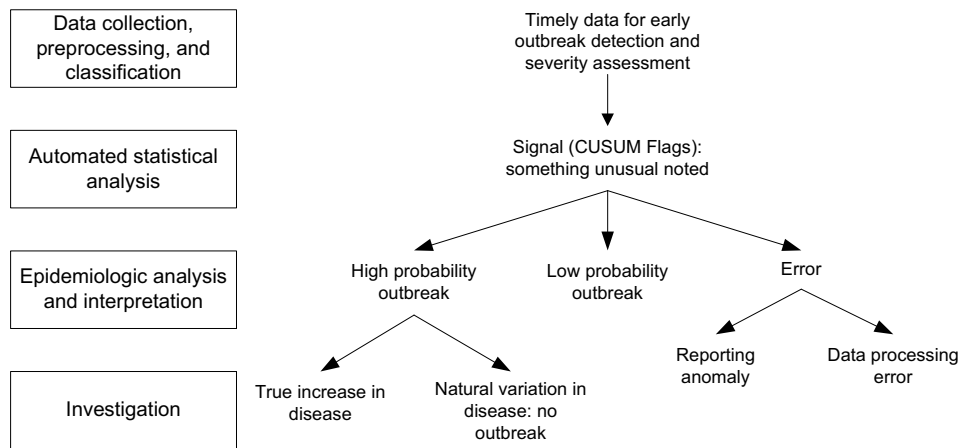
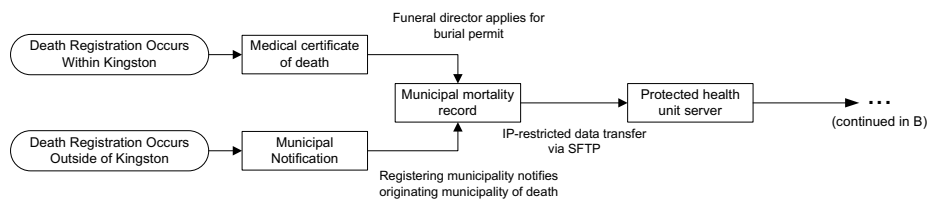
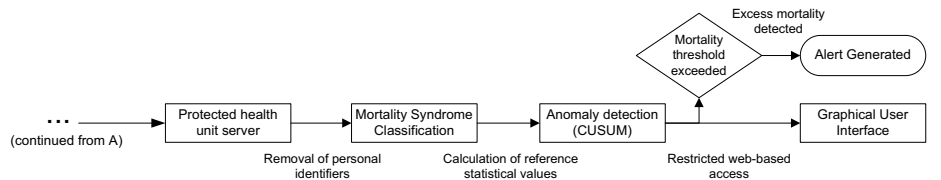


Figure 2. A. The possible ways that a mortality event is captured to generate a municipal mortality record
 B. The mortality classification, analysis and alert generation steps that follow weekly municipal data updates

A. Mortality Event Capture



B. Mortality Data Processing, Classification, Analysis and Display



Data sharing, privacy, and confidentiality

Under the Health Protection and Promotion Act, municipalities are enabled to release vital statistics information to Medical Officers of Health. The Ontario Public Health Standards require that health units collect surveillance data and conduct epidemiological analysis for the purpose of communicating with community partners and mitigating public health impacts in advance of, during and after a public health emergency.¹⁰ A data sharing agreement between the City of Kingston and the KFL&A health unit facilitated regular municipal mortality data updates.¹¹ The collection, use and disclosure of any personal health information comply with Ontario's Personal Health Information Protection Act. In addition, the Research Ethics Board at Queen's University provided ethics approval for this research project.

Data collection and pre-processing

The City of Kingston provided weekly updates from the municipal mortality index using a secure file transfer protocol connection with a firewall-protected server administered by KFL&A public health. After personal identifiers were removed, the remaining data fields included the date of death, age at death, cause of death, and city of

diately incorporated into the baseline, and consecutively high values will generate an alert. The C3 method has the highest sensitivity and uses an offset 7-day baseline similar to C2, but with a threshold based on a 3-day average run length of the one-sided positive CUSUM. All three CUSUM methods were implemented in the MSS.

The most significant difference in the MSS implementation of CUSUM is that a weekly analysis period is used instead of the daily period found in EARS. The relatively small number of deaths in Kingston (approximately 3-4 daily) would make daily analysis subject to unacceptable levels of variability. With baseline periods lasting weeks, seasonal trends such as increased mortality over cold weather months due to influenza seen in economically-developed countries become more significant.¹⁶ The graphical interface incorporates retrospective seasonal averages and standard deviations to provide context for elevated CUSUM flags. The challenge most alert-generation methods face is achieving an acceptable compromise between false positives and the detection of meaningful aberrations in the system of interest. In the future, e-mail alerts will be generated to prompt human intervention when mortality thresholds have been exceeded. Our thresholds are still under evaluation and are not presented in this paper.

RESULTS

Retrospective analysis

Between January 1, 1997 and December 31, 2008, there were 18,317 deaths registered by the City of Kingston. Burials by funeral homes affiliated with Kingston represent the majority of the dataset. This subset of registered deaths had the shortest reporting lag to the City. Additionally, after 2009, this subset provided the most thorough information regarding causes of death. In contrast, burials elsewhere within KFL&A had longer reporting lags and often lacked the age of the deceased. For example, in 2008, 62.9% of deaths were buried in Kingston. The median reporting lag for these deaths was 4 days, with the mean being 6 days, while burials occurring outside of Kingston (28.5% of deaths in 2008) had a median reporting lag of 6 days, and a mean of 15 days.

The cause of death was unavailable in 8% of records, primarily due to ongoing coroner investigations. This value was consistent during the span of the retrospective analysis for deaths occurring both within Kingston and the KFL&A region. A further 13% of the dataset stated "cardiac arrest", "respiratory failure", or some variation of these terms as the only provided cause of death. When used alone, these terms do not provide any cause-specific information for epidemiological analysis.

Pandemic H1N1 and mortality surveillance

Though still in its infancy, the MSS proved useful to public health officials within the Kingston jurisdiction during the fall H1N1 outbreak. Figure 4 shows Kingston-area Emergency Department (ED) visits for respiratory illness compared with mortality over two influenza seasons. KFL&A public health officials monitored the MSS alongside acute care syndromic surveillance data throughout the outbreak. The large increase in ED visits for respiratory illness between October and November 2009 was assumed to be caused by H1N1. Acute care resources were significantly impacted during the outbreak, with greater utilization of mechanical ventilation and

more admissions to intensive care units for pneumonia & influenza than in the previous years.¹⁷ The strain on resources also occurred earlier in the year than typical seasonal influenza, with an epidemiological shift to the left. In contrast to the ED visits, the 2009 outbreak of pH1N1 influenza did not adversely affect mortality in the KFL&A area compared to the 1997-2008 reference period. Mortality from all causes remained within 1% of the annual average for the region and pneumonia & influenza deaths were 10% lower. The expected seasonal increase in mortality was observed in January 2010, likely attributable to various circulating respiratory viruses, influenza and pneumonia.¹⁶ When compared to ED visits as another indicator of disease, mortality often exhibits time lag subject to the availability of specialized hospital services for critically ill patients such as invasive mechanical ventilation. Length of hospitalization was not included within the dataset and was outside the scope of this analysis.

DISCUSSION

System limitations

The fact that recent legislative changes to the Vital Statistics Act mean that municipalities are no longer required to record causes of death may make it more difficult to approach municipalities that have already omitted this information from their indices. Since our dataset captures data from municipalities that share death registration information with Kingston, ongoing cooperation with municipal partners is essential to protect the quality of these records. Early dialogue with targeted municipalities regarding their continued inclusion of causes of death could maintain the integrity of these datasets for future inclusion. Additionally, while omission of the cause of death may reduce the utility of cause-specific analysis, data can still be used to gather trends for all-cause mortality. In Kingston, improvements in data quality from the inclusion of additional causes of death in the mortality data stream may make it possible to modify the pneumonia & influenza syndrome to more closely approximate the ICD standard. We are in discussions with the regional coroner regarding the integration of coroner-determined cause of death into our system.

The quality of information contained within the dataset is subject to the diligence of physicians when completing the medical death certificate, and of transcriptionists who transcribe data for electronic transmission. Different medical education interventions have been shown to significantly reduce the frequency of completion errors.¹⁸ The regional coroner is involved in efforts to enrich death certificate training during postgraduate years, which could improve data quality going forward. Similar efforts are underway with municipal partners to discuss how to reduce transcription errors.

To better capture deaths within the KFL&A area but outside the City of Kingston, the Town of Greater Napanee (2006 census population 15,400) has agreed to participate in this project. Their municipal council recently approved a data-sharing agreement in anticipation of providing regular mortality updates based on the Kingston model. The technical infrastructure implemented in Kingston was developed internally but could be adapted to handle mortality data streams from additional jurisdictions such as Napanee. It could be also used as a model upon which other municipalities and health units base their own health surveillance systems.

Future directions

As demonstrated during H1N1, mortality data can be an important data source for evidence-based decision making by public health officials during a pandemic. Utilization of municipal vital statistics has facilitated faster access to mortality data than has traditionally been possible in Ontario, albeit with a small localized dataset. Anomaly detection methods for alert generation will continue to be evaluated. However, within the existing mortality registration framework, any measured trends may lag behind the real phenomenon by days or weeks. Ultimately, the ideal solution would incorporate national or provincial mortality data with mandatory reporting within 24 hours, including the medical certificate of death, to facilitate spatial mapping and temporal analysis. Integration of mortality surveillance along with other real-time data streams into an integrated electronic public health dashboard could provide decision-makers with timely information during public health emergencies.

CONCLUSIONS

Municipal data enabled automated surveillance of mortality in the KFL&A region with weekly updates. Retrospective analysis over a 10-year period established baseline mortality rates in the region. While evaluation of the usefulness of this system as a module in a comprehensive real-time public health electronic surveillance system is ongoing, the MSS provided public health officials with timely information regarding the impact of H1N1 in KFL&A. Spatial mapping and temporal analysis could further exploit the potential of this data source to enhance the investigational capabilities of public health.

REFERENCES

- Schlegelmilch J, Gunn J, Pendarvis J, Donovan M, Vinjé J, Widdowson M, et al. Bio-surveillance and enhanced situational awareness. *Adv Dis Surveillance* 2007;4:191.
- Fallon K, Boone D. Death certificate surveillance - New Hampshire. *MMWR* 2004;53(Suppl):236.
- Muscattello D, Morton P, Evans I, Gilmour R. Prospective surveillance of excess mortality due to influenza in New South Wales: Feasibility and statistical approach. *Commun Dis Intell* 2008;32:435-42.
- Canadian Medical Association. Lessons from the frontlines: A collaborative report on H1N1 2010.
- Ontario Ministry of Health and Long-Term Care. Ontario Health Plan for an Influenza Pandemic 2008 (Updated September 23, 2008). Available at: http://www.health.gov.on.ca/english/providers/program/emu/pan_flu/pan_flu_plan.html (Accessed June 10, 2009).
- Public Health Agency of Canada. Canadian Pandemic Influenza Plan for the Health Sector. (Updated December 9, 2006). Available at: <http://www.phac-aspc.gc.ca/cpip-pclcpi/index-eng.php> (Accessed June 10, 2009).
- Buehler J, Hopkins R, Overhage J, Sosin D, Tong V. Framework for evaluating public surveillance systems for early detection of outbreaks: Recommendations from the CDC Working Group. *MMWR Recomm Rep* 2004;53(RR-5):1-11.
- Donovan T, Moore KM, VanDenKerkhof EG. Employee absenteeism based on occupational health visits in an urban tertiary care Canadian hospital. *Public Health Nurs* 2008;25(6):565-75.
- Moore KM, Edgar BL, McGuinness D. Implementation of an automated, real-time public health surveillance system linking emergency departments and health units: Rationale and methodology. *CJEM* 2008;10(2):114-19.
- Ontario Ministry of Health and Long-Term Care. Ontario Public Health Standards. Toronto, ON: Queen's Printer for Ontario, 2008.

- Report No. 09-172: Data Partnership Agreement with Kingston Frontenac Lennox and Addington Public Health. Available at : http://www.cityofkingston.ca/pdf/council/agenda/2009/A13_Rpt57.pdf (Accessed June 10, 2009).
- Knuth DE. *The Art of Computer Programming. Volume 3: Sorting and Searching*, 2nd ed. Reading, MA: Addison-Wesley, 1998.
- Stroup DF, Williamson GD, Herndon JL. Detection of aberrations in the occurrence of notifiable diseases surveillance data. *Stat Med* 1989;8:323-29.
- Farrington CP, Andrews NJ, Beale AD, Catchpole MA. A statistical algorithm for the early detection of outbreaks of infectious disease. *J Royal Stat Soc Series A* 1996;159:547-63.
- Lucas JM. Counted data CUSUM's. *Technometrics* 1985;27:129-44.
- Reichert TA, Simonsen L, Sharma A, Pardo SA, Fedson DS, Miller MA. Influenza and the winter increase in mortality in the United States, 1959-1999. *Am J Epidemiol* 2004;160(5):492-502.
- Canadian Institute for Health Information. H1N1 in Canada - A Context for Understanding Patients and Their Use of Hospital Services. 2010 (Updated February 11, 2010). Available at: http://www.cihi.ca/cihiweb/disPage.jsp?cw_page=AR_3310_E (Accessed July 19, 2010).
- Myers KA, Farquhar DR. Improving the accuracy of death certification. *CMAJ* 1998;158(10):1317-23.

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RÉSUMÉ

Contexte : La pandémie d'influenza H1N1 (pH1N1) survenue au Canada en 2009 a montré qu'il faut accroître la surveillance au palier local et régional pour que les médecins et la santé publique puissent prendre des décisions fondées sur des données scientifiques. Nous décrivons la raison d'être, la méthode et les constatations préliminaires de la mise en œuvre d'un système automatisé de surveillance de la mortalité (SSM) dans la circonscription sanitaire de Kingston, Frontenac et Lennox et Addington (KFL&A).

Méthode : Le SSM utilisait un cadre Internet automatisé avec transfert sécurisé des données. Un accord de partage des données conclu entre le médecin-hygiéniste local et la ville de Kingston a facilité l'actualisation hebdomadaire des données de mortalité. Les décès dus à l'influenza ont été classés selon la cause de décès (par mots clés) et par un algorithme phonétique pour saisir les orthographes alternatives. Le modèle de détection des anomalies était une version modifiée de l'algorithme de somme cumulée du système EARS (*Early Aberration Reporting System*).

Résultats : Nous avons établi les taux de mortalité de référence dans la région par une analyse rétrospective des données municipales de mortalité sur une période de 10 ans. Les données du SSM surveillées durant la saison d'influenza pH1N1 n'ont montré aucun impact significatif sur le fardeau de mortalité ni sur le moment des décès dans la circonscription sanitaire de KFL&A.

Conclusion : Les données municipales ont permis de surveiller la mortalité dans la région de KFL&A et d'actualiser les résultats chaque semaine. D'autres municipalités pourraient participer à ce projet de surveillance en utilisant le modèle de Kingston sans avoir à y consacrer des sommes importantes sur une base permanente. On poursuit les efforts pour améliorer la qualité des données fournies par les médecins et leur transcription. L'intégration des données de mortalité et d'autres flux de données en temps réel dans un tableau de bord électronique de la santé publique pourrait permettre aux décideurs d'obtenir de l'information en temps utile durant les urgences sanitaires.

Mots clés : pandémies; plan catastrophe; surveillance de la santé publique; surmortalité