MIXED RESEARCH

A Multi-function Public Health Surveillance System and the Lessons Learned in Its Development: The Alberta Real Time Syndromic Surveillance Net

Shihe Fan, PhD,[1] Corinne Blair,[2] Angela Brown, MSc,[1] Stephan Gabos, MD,[3] Lance Honish, MSc,[1] Trina Hughes, BAdm,[4] Joy Jaipaul, MN,[1] Marcia Johnson, MPH, MD,[1] Eric Lo, MSc,[2] Anna Lubchenko, BSc,[1] Laura Mashinter, MSc,[1] David P. Meurer, BScN,[5,6] Vanessa Nardelli, MSc,[1] Gerry Predy, MD,[1] Liz Shewchuk,[2] Daniel Sosin, MD, MPH,[7] Bryan Wicentowich, BSc,[2] James Talbot, MD, PhD[3]

ABSTRACT

Objective: We describe a centralized automated multi-function detection and reporting system for public health surveillance – the Alberta Real Time Syndromic Surveillance Net (ARTSSN). This improves upon traditional paper-based systems which are often fragmented, limited by incomplete data collection and inadequate analytical capacity, and incapable of providing timely information for public health action.

Methods: ARTSSN concurrently analyzes multiple electronic data sources in real time to describe results in tables, charts and maps. Detected anomalies are immediately disseminated via alerts to decision-makers for action.

Results: ARTSSN provides richly integrated information on a variety of health conditions for early detection of and prompt action on abnormal events such as clusters, outbreaks and trends. Examples of such health conditions include chronic and communicable disease, injury and environment-mediated adverse incidents.

Discussion: Key advantages of ARTSSN over traditional paper-based methods are its timeliness, comprehensiveness and automation. Public health surveillance of communicable disease, injury, environmental hazard exposure and chronic disease now occurs in a single system in real time year round. Examples are given to demonstrate the public health value of this system, particularly during Pandemic (H1N1) 2009.

Key words: Public health; public health informatics; syndromic surveillance; disease surveillance

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

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Timely surveillance information is increasingly important in this age of global climate change and globalization of travel, trade and commerce; infectious diseases can now emerge more rapidly and disperse more widely, as evidenced in the recent outbreaks of severe acute respiratory syndrome (SARS)[1-3] and Pandemic (H1N1) 2009 (pH1N1).[4,5] Bioterrorism has also become a pressing public health concern since the 2001 anthrax attacks[6,7] in the United States.

Early detection and timely notification of public health threats are key goals for syndromic surveillance[8-10] to make earlier investigation and targeted intervention possible – lessons learned from the well-publicized 1993 *Cryptosporidium* outbreak in Milwaukee, USA[11] and the 2000 *Campylobacter jejuni* and *Escherichia coli* O157:H7 outbreak in Walkerton, Canada.[12] In both cases, retrospective analyses found earlier syndromic evidence[11,13] before traditional surveillance methods identified these outbreaks. Automated syndromic surveillance identifies probable cases or outbreaks using timely pre-diagnostic or pre-laboratory information,[8-10] whereas traditional methods either do not collect syndromic information or rely heavily on laborious manual collation of information derived from health care provider interviews, clinical diagnoses and laboratory results.

The local health authority serving the Edmonton Zone of the Alberta Health Services (i.e., the City of Edmonton and surrounding area of Alberta) has rich electronic health information, and most of it was inadequately utilized previously for public health surveillance. Surveillance of communicable disease was historically paper-based, with manual electronic data entry; injury and chronic disease surveillance was conducted separately by different departments. No central surveillance system capable of automatically analyzing and reporting health data existed in the Edmonton

Author Affiliations

1. Population & Public Health, Alberta Health Services, Edmonton, AB
2. Information Services, Alberta Health Services, Edmonton, AB
3. Alberta Health and Wellness, Edmonton, AB
4. Transition Services, Alberta Health Services, Edmonton, AB
5. Department of Emergency Medicine, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, AB
6. Emergency Department, University of Alberta Hospital, Alberta Health Services, Edmonton, AB
7. Centers for Disease Control and Prevention, Atlanta, GA

Correspondence: Shihe Fan, Suite 104 West Tower, 14310-111 Ave NW, Edmonton, AB T5M 3Z7, Tel: 780-342-0215, Fax: 780-342-0248, E-mail: shihe.fan@albertahealthservices.ca

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Conflict of Interest: None to declare.

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Table 1. Summary of the Data Sources That Are Currently in the Data Repository of the Alberta Real Time Syndromic Surveillance Net

Data Source	Description	Data Characteristic	Data Elements	Extraction, Transformation and Loading Frequency	Records Per Year
Health Link calls	Selected telephone calls to Health Link Alberta	Syndromic	Call date and time, protocol, disposition (i.e., the nurse's advice for patient care) and patient demographic information (gender, date of birth and residence postal code)	15 min.*	100,000 – 125,000
Emergency department visits	Visits to the emergency department of six local hospitals and three urgent care centres	Syndromic, diagnostic	Visit date and time, patient demographic information, chief complaint, initial ED physician diagnosis, discharge disposition, transfer location and hospital visited	15 min.†	380,000 – 450,000
School absenteeism	Student absenteeism records of 250 elementary schools	Syndromic	Name and postal code of the school, grade, age, and residence postal code of the absent students, as well as the duration of each absence (half or full day)	Daily	500,000 – 650,000
Laboratory reports	Laboratory test results of notifiable diseases	Diagnostic	Date and time of specimen collected, order received, test performed, and result reported, specimen type, specimen source, patient demographic information, test procedure, test result, organisms tested for, antibiotic resistance of the organisms and other relevant information	15 min.‡	Approximately 175,000 laboratory orders
Forms	Online data forms	Syndromic, Diagnostic	Varying with specific forms	As required	

* Average time from a nurse answering a call at Health Link Alberta to the time when the call record is seen by an ARTSSN user is 27.9 (SD = 7.0) minutes (30 tests on 3 different days). Note that the nurse may spend a variable amount of time answering the call and ARTSSN receives the record only after the call is closed. The data transmission time is therefore substantially less than indicated.
† Average time from a visit being triaged at an emergency department to the time when the record is seen by an ARTSSN user is 15.7 (SD = 4.6) minutes (30 tests on 3 different days).
‡ Not tested.

Table 2. Annual Number of Emergency Department Visits by Young People (10-24 Years Old) From 2005 to 2009 Registered in the EDIS System

Health Concern		Year				
		2005	2006	2007	2008	2009
All reasons	Total visits	76,688	80,702	78,023	76,699	80,576
Injury	Total visits	26,957	27,761	26,004	24,136	23,387
	Admitted/transferred	1023 (3.79) *	1129 (4.1)	1096 (4.2)	1096 (4.5)	1155 (4.9)
	Dead	6 (0.02)	10 (0.04)	8 (0.03)	12 (0.05)	8 (0.03)
% of injury visits to total ED visits		35.2	34.4	33.3	31.5	29.0

* Numbers in parentheses for admitted/transferred visits and deaths are percentages of total visits for injuries.
Note the declining trend of the percentage of injury visits in relation to total visits for the period.

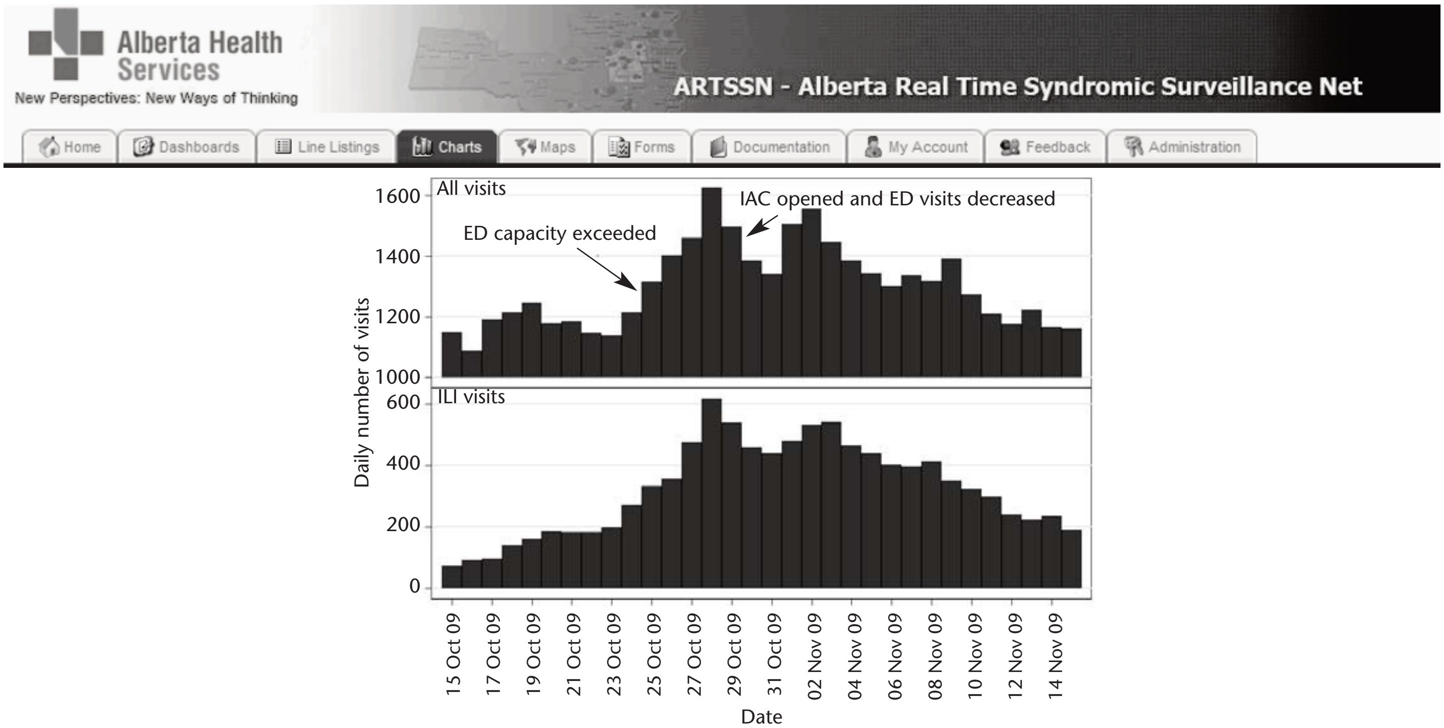
Zone. The Alberta Real Time Syndromic Surveillance Net (ARTSSN) was developed with three goals: 1) improve upon traditional paper-based, fragmented public health surveillance using a centralized automated system; 2) enhance routine public health surveillance through effective use of existing Provincial Electronic Health Record data for earlier detection of cases, clusters, outbreaks and trends of communicable disease, injury, and environmental hazard exposure; and 3) track the effectiveness of public health interventions. This paper describes ARTSSN and the lessons learned in its development as a real-world application of syndromic surveillance.

Data and system architecture

ARTSSN is a modular system[14] consisting of multiple real time Health Level 7 (HL7) data feeds from operational systems and selective data from the Provincial Electronic Health Record repository Alberta Netcare, a supporting data repository, a provincial Enterprise Master Patient Index, a terminology translation service and a user interface. In its first phase of development, ARTSSN obtained a privacy impact assessment approval for four streams of electronic data for residents of the Edmonton Zone: 1) telephone calls to Health Link Alberta; 2) emergency visits; 3) laboratory tests; and 4) school absenteeism (Table 1).

Health Link Alberta (HL) provides a 24/7/365 province-wide service for health advice and information. Registered nurses use a decision support tool of protocols to assess calls; each protocol consists of detailed algorithms for triaging symptom-based chief complaints (CC) and providing advice and information for managing symptoms and directing patients to appropriate health care. At the time of writing, HL had 210 protocols; ARTSSN used 133. Six hospitals and three urgent care centres provide emergency visits data through an Emergency Department (ED) Information System (EDIS)[15] or an electronic triage information system (eTRIAGE).[16] Data on school absenteeism are obtained from 250 elementary schools (kindergarten to grade 6) in the City of Edmonton and nearby Parkland County; the student population in each participating school is updated in late September and early February of each school year. Positive laboratory results of notifiable diseases that are provincially legislated or declared by medical officers of health (MOH) are received from the Alberta Provincial Laboratory for Public Health or Dyna-LIFE_{DX} Laboratory (Edmonton, Canada). These data are result-based, not volume-based; they are diagnostic and used for surveying mandatory notifiable diseases and confirming syndromic signals.

Figure 1. Two screenshots showing the use of ARTSSN for monitoring emergency department (ED) visit capacity and the effect of opening a mass influenza assessment centre in Edmonton on relieving the visitation pressure on ED capacities during the second wave of Pandemic (H1N1) 2009



The top panel shows the pressure build-up before the mass Influenza Assessment Centre (IAC) was opened in Edmonton and the immediate decrease in emergency department (ED) visits the same day when the IAC was opened. The bottom panel shows the dynamics of ED visits for influenza-like illness (ILI). On October 28, 2009, 38.1% of the ED visits were ILI.

The proprietary data repository is a scalable Oracle™ database. Data elements (see Table 1) are first extracted from the feed databases, transformed, cleansed, checked for completeness and reorganized. Personal identifiers are replaced with meaningless pseudo-keys. The repository also receives data manually entered into electronic forms through an online survey module of the user interface. Population data for the Edmonton Zone, as derived from the provincial health insurance registry and broken down by gender, age group and geographic area, are contained in the repository for rate calculation.

The terminology translation service uses look-up tables for syntactic and semantic translation. It unifies terms within and between data sources and translates CCs (ED data) and protocols (HL data) to a standard set of syndromes and “health concerns”, and translates school absenteeism to a standard set of reasons for absence. Each health concern consists of similar syndromes (physiologically or anatomically) and is named accordingly, e.g., all cardiovascular syndromes are grouped under the cardiovascular heading.

The user interface was developed by Voxiva (Washington, DC). It is intranet-based and secured behind a firewall for authorized uses only, and has submodules for 1) data analysis and visualization, 2) automated notification, and 3) system administration.

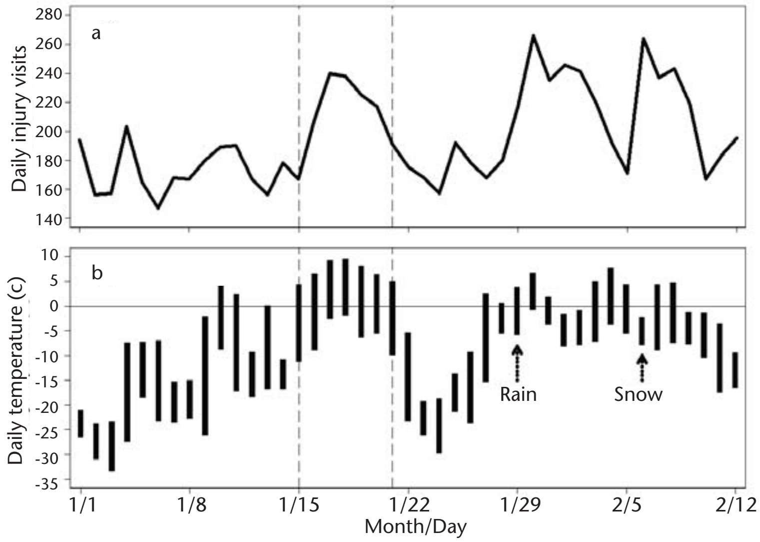
The data analysis and visualization submodule can present results in tables, charts or maps by person, place, time, CC, discharge disposition, laboratory test and result, or disease agent either by count or by rate. These products can then be saved for future reference, exported for reporting, or placed on online dashboards for real-time surveillance. Line listings of data can also be exported for off-line analyses or scientific research.

The automated notification submodule continuously compares incoming data to pre-set thresholds for the diseases or syndromes under surveillance by person, place and time according to algorithms configured within a series of notification templates. The algorithms are based either on rate or count, depending on the diseases or syndromes. If a threshold is surpassed, prompt notification is automatically dispatched to designated personnel via means specified in their notification subscription. For instance, 43 alerts of school absenteeism due to illness ≥10% were sent to the ARTSSN epidemiologist on November 5, 2009 during Wave 2 of pH1N1 2009. This automated notification improves traditional surveillance markedly since a very large number of conditions can now be effectively surveyed by many combinations of person, place and time. This degree of examination would be extremely laborious and expensive using traditional methods.

The system administration module controls, among other functions, access to the system, data sources, and functions of the system. Users are first grouped into a role matrix according to their responsibility and institutional affiliation. A profile of privileges is built for each role; users sharing a common role are further controlled by manipulating their privileges, such as being limited to only a single data source or reduced system functions.

A novel feature of ARTSSN is the patient re-identification mechanism. Under the Public Health Act in Alberta, notifiable diseases must be reported to the local public health department for investigation. Consequently, a drill-down function was built in the system for authorized users such as MOH, communicable disease control nurses or environmental health officers, which allows them to re-identify individuals using the Enterprise Master Patient Index via the pseudo-key.

Figure 2. Relationship between daily emergency department visits for injuries (a) and daily maximum/minimum temperatures (b) from January 1 to February 12, 2009



During the specified data period, unusual warming periods (daily maximum temperatures above zero) intermingled with rain and light-snow events. Each warming episode melted the packed snow surface in daytime and refroze it at night, which caused icy road conditions and increased emergency visits for injuries. One such warming period (between 1/15 and 1/22) is highlighted in the figure.

Surveillance examples

ARTSSN is multi-functional and has many potential uses in public health surveillance. Figure 1 shows its use in pandemic surveillance,[17] using ED visitation data during pH1N1 2009 to inform the timely opening of a mass influenza assessment centre and then evaluating its impact on relieving pressure in the EDs. Figure 2 demonstrates use for injury prevention. In January and February of 2009, the local public health department used media assistance to advise the public of treacherous road conditions and precautions required when driving or going outdoors. Injury prevention is one of the five key areas recommended for improving the health of Canadian children.[18] From 2005 to 2009, approximately one third of ED visits by young people were injury-related (Table 2).

DISCUSSION

ARTSSN followed four design principles: automated, real-time, routinely useful and locally useful. Automation minimizes interruptions to real-time surveillance even during the most resource-challenging conditions like pH1N1 2009 (Figure 1). Each ED visit or HL call about influenza-like illness (ILI) or laboratory-confirmed pH1N1 case is automatically acquired by the data repository and updated on online dashboards for timely understanding of the pandemic progressing in the community. The information is then relayed to Emergency Operation Centres to inform their pandemic responses. Real-time information also enables ED managers to promptly re-allocate patient care and infection prevention and control resources based on ED patient flow, punctually intervene in screening ILI patients and significantly improve ILI data quality. The pH1N1 2009 experience demonstrates that ARTSSN is truly useful to both the data user and provider.[19]

Real-time surveillance reduces recall bias and improves interpretation of statistical associations since immediate temporal, spatial and population connections are possible as events are unfolding (Figure 2). Real-time surveillance in ARTSSN gives public health practitioners a new tool to survey injury, environmental hazard exposure, chronic and communicable disease comprehensively for improved and targeted health protection and promotion.

Being routinely useful enables ARTSSN to gain wide user support; 31 users (groups), including data providers, MOH, communicable disease and environmental health epidemiologists in the Edmonton Zone, as well as all MOH in the province, now have real-time information for decision-making. Although biological,[6,7] nuclear or radioactive terrorist attacks are all potential threats to public health, such attacks are rare compared to the frequency of infectious disease outbreaks, unintentional injuries or severe weather-related events. A system solely dedicated to small probability events may be unsustainable over time at the local level.

Being locally useful[20] means that ARTSSN carefully balances the needs of both the data provider and data user. Strategies included rapid feedback about the quality, meaning and limitation of the data; help in defining the requirements and functions of ARTSSN; and joint efforts in the development of surveillance products. Evaluation was done in parallel with system development by independent evaluators for simplicity, acceptability, utility and other aspects following established frameworks for evaluation of public health surveillance systems.[21,22] Issues or concerns raised were assessed and resolved promptly. Consequently, the user interface is more intuitive; new users can become proficient with two to three hours of instruction.

ARTSSN was developed through rapid successions of data collection, analysis, interpretation and dissemination in iterative "plan, do, check, and act" cycles, avoiding past practice of sequentially optimizing each individual step before moving to the next. For example, HL data were first extracted into the repository; line listings, graphs, tables and maps were then developed using other software before the user interface was ready. Feedback about these prototypes was incorporated into the next development cycle. These rapid, iterative cycles uncovered deficiencies earlier, gained user acceptance faster, and obtained support more broadly, allowing ARTSSN to be implemented more swiftly (<2 years from launching to operation) than some legacy surveillance systems.

The data repository is critical to ARTSSN. It facilitates data-flow from the source to the user interface without interfering with the stability and functionality of the operational databases. Data pseudonymization simplifies privacy impact assessment approval for the system and ethics approval for research use of data. This central repository approach differs from other distributed systems where the data reside with their originator.[23-25] A key advantage to ARTSSN is that the database is a centralized model within a single health organization, making the repository development and maintenance easier. This centralization significantly improves public health surveillance through the multi-functions of ARTSSN by avoiding fragmentation that has plagued traditional surveillance systems.

The Pandemic (H1N1) 2009 showed that automated data acquisition in ARTSSN could be disrupted if the source capacity was exceeded[19] (see Figure 1). For instance, the repository was unable to receive call data when Health Link Alberta was forced to streamline call recording using paper instead of its time-intensive electronic system. Moreover, unlike other systems,[14,26,27] ARTSSN lacks statistical modeling capability. Thresholds for the syndromes and diseases under surveillance require individual programming based on historic data. Difficulties remain in simultaneously deciphering aberration signals from multiple data streams and in determining the syntactic and semantic relationship in free-texted medical records in some new databases as ARTSSN is expanding from a regional to a provincial system. These issues are being addressed by working with data providers and by collaborating with university researchers on natural language processing and statistical analysis.

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RÉSUMÉ

Objectif : Nous décrivons l'*Alberta Real Time Syndromic Surveillance Net* (ARTSSN), un système multifonction, centralisé et automatisé de détection et de production de rapports de surveillance de la santé publique. Il s'agit d'une amélioration par rapport aux anciens systèmes sur papier, souvent fragmentaires, limités par la collecte de données incomplètes, par des capacités d'analyse insuffisantes et par l'impossibilité de fournir de l'information en temps utile pour les interventions de santé publique.

Méthode : L'ARTSSN analyse simultanément plusieurs sources de données électroniques en temps réel et en présente les résultats sous forme de tableaux, de diagrammes et de cartes. Les anomalies décelées sont immédiatement communiquées aux décideurs pour qu'ils puissent agir.

Résultats : L'ARTSSN offre une information très bien intégrée sur divers troubles médicaux pour faciliter le dépistage précoce des événements anormaux (concentrations de cas, éclosions, tendances) et une intervention rapide. Les troubles surveillés sont entre autres les maladies chroniques et transmissibles, les blessures et les incidents défavorables d'origine environnementale.

Discussion : Les grands avantages de l'ARTSSN par rapport aux méthodes sur papier sont sa rapidité, sa complétude et son automatisation. Il est maintenant possible d'assurer la surveillance des maladies transmissibles, des blessures, de l'exposition aux dangers environnementaux et des maladies chroniques importantes avec un seul système, en temps réel et à longueur d'année. Nous donnons des exemples pour démontrer l'utilité du système pour la santé publique, tout particulièrement durant la pandémie d'influenza H1N1 de 2009.

Mots clés : santé publique; informatique en santé publique; surveillance syndromique; surveillance des maladies