CHAPTER 6: Telehealth detection of gastrointestinal illness: An early warning system for bioterrorism

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Introduction

In the post 9-11 era, the threat of bioterrorism looms large[1]. International terrorist activities have highlighted our lack of preparedness for biological attacks and have focused the attention of local and national health resources on methods to enhance detection of an event[2-6]. In North America, water supply and distribution systems and the food industry represent potential targets for terrorist activity because of the essential roles these industries play in day-to-day life and the relative ease of intentional contamination[2,7-10]. The United States government intelligence experts classify the threat to municipal water supplies as low probability but one with severe medical, public health and economic effects[11]. Terrorism through intentional food and water tampering has already occurred in the United States. In 1984 *Salmonella* contamination of salad bars was used to affect voter turnout at a local election and in 1997 a laboratory worker intentionally contaminated a co-worker's food with *Shigella*[12,13]. Health care providers must maintain a high index of suspicion for bioterrorism because intentional outbreaks may resemble naturally occurring disease and involve endemic pathogens.

The globalization of food production and centralization of food and water distribution have markedly increased society's risk of large outbreaks. In 2000 a municipal well in Walkerton, Ontario was contaminated with *Campylobacter jejuni* and *Escherichia coli* 0157:H7 resulting in 2300 ill and seven deaths[14]. Early detection of the first symptomatic cases is an important objective in bioterrorism surveillance. Pathogens most likely to be used by terrorists produce diseases characterized in their early stages by nonspecific symptoms and signs[6]. Potential benefits of early detection of infectious disease include rapid post exposure prophylaxis or treatment, allocation of health resources and implementation of public health measures (quarantine, isolation, boil water advisories, vaccination programs) to limit spread of disease[15].

Syndromic surveillance is an emerging field in the science of epidemiological surveillance developed in response to the threat of bioterrorism. Intended to be complementary to conventional methods, syndromic surveillance converts clinical data collected electronically at the point of care into surveillance information. A number of non-traditional data sources have been used for syndromic surveillance including emergency department (ED) visits[16-18] and telephone helpline calls[19-25]. Most syndromic surveillance programs in North America are integrated into the health care system at the earliest points of care. In Ontario early access points are EDs, primary

care providers and Telehealth Ontario (Telehealth). Recent studies show integration of multiple data sources improves specificity but none have determined the most effective data streams or method of integration[26,27]. The National Health Service (NHS) Direct helpline in the United Kingdom is a system of 22 independent call centers that use real-time call data for health surveillance. Retrospective and prospective evaluation of NHS Direct shows promise as an early warning system for influenza and GI illness[19-22]. Although analogous to NHS Direct, Telehealth is better suited to provincial health surveillance because of its centralized database and standardized computerized decision tree. The objective of this study is to examine the temporal relationship of ED visits and Telehealth calls for GI illness. It is hypothesized that Telehealth calls will be a complimentary data source for Ontario ED discharges thereby enhancing options for early detection of bioterrorist events.

Methods

Study design

This is a retrospective study of GI illness data for a 22-month period between June 1st, 2004 and March 31st, 2006. Anonymized data were obtained from the Telehealth and the Canadian Institute of Health Information (CIHI) NACRS databases. Use and storage of data complied with the privacy policies and procedures of Kingston, Frontenac, Lennox and Addington Public Health. The Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board approved this study as part of a larger research project by the Queen's University Emergency Syndromic Surveillance Team (QUESST).

Agents of Bioterrorism

The Centers for Disease Control and Prevention published a system classifying key agents according to their potential for adverse public health impact[28]. Category A agents are associated with the highest mortality and transmissibility, require specialized laboratory testing and medical treatment, and have the highest potential for intentional release. Category B agents result in lower, but significant, mortality and morbidity. Category C agents reflect emerging infectious diseases that may present future bioterrorist risk. (Table 1) Except for anthrax (Category A), outbreaks of gastrointestinal (GI) illness following a bioterrorist event will most likely be caused by Category B agents, particularly those associated with food and water safety[7,29,30].

Background on the National Ambulatory Care Reporting System (NACRS)

As of July 2006, 186 institutions in Ontario submit clinical, administrative and demographic data to the NACRS using ICD-10-CA diagnostic codes[31,32]. Data abstraction is done by trained hospital health records staff at the conclusion of each patient visit. CIHI audits all submitted data to identify duplicate records, missing data or inconsistencies in data transmission. If errors are found, the submitting facility is asked to correct these abstracts. Reliability of coding data collected by CIHI ranges from 74-96%[33]. Only ICD-10-CA codes that dealt with a communicable GI illness were included in the data set. (Table 2)

Background on Telehealth Ontario

Telehealth is a toll-free helpline provided by the Ontario Ministry of Health, Long Term Care (MOHLTC) and is available to all residents of the province. Services have been contracted to Clinidata since December 2001. Trained, experienced registered nurses provide confidential advice for any general health question. The service is available 24 hours a day, 7 days a week and 365 days a year (24/7/365) and is offered in the Canadian official languages, English and French, with translational support available in 110 languages[34]. Other than the official languages Mandarin, Cantonese, Farsi, Italian and Portuguese are most often requested[34]. Each nurse-led call lasts an average of 10 minutes and concludes with a disposition to the most appropriate form of care. The decision-based software is evidence-based, expert driven, and uses dichotomous questioning[35].

Data is collected in the form of 486 guidelines which have been reviewed and approved by a team of university-affiliated medical experts[35]. Telehealth guidelines were categorized by QUESST *a priori* into one of 32 syndrome names (e.g. respiratory upper, trauma, GI, etc) after review of classifications used by existing syndromic surveillance systems including the Rapid Outbreak Detection System (RODS), Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE) and the NHS Direct. For the purpose of this study only calls coded as GI were analyzed. (Table 3)

Statistics

The Telehealth and NACRS data sources were compared by fitting time-series models and estimating a cross-correlogram at different lags (weekly). Data sets were transformed and detrended by differencing and autoregressive moving average models were fitted to the differenced series to ensure the residuals were normally distributed

and independent. Autocorrelation and partial autocorrelation functions of the models were examined to determine autoregressive and moving average parts of the models. Residuals were checked for normality against the fitted values, and checked for white noise by the Portmanteau test. Spearman rank tests were performed and then cross-correlations were estimated for residuals (to account for seasonality and trends) at different lags with the limit of statistically significant correlation being $2/\sqrt{(N-1)}$ where N is the number of intervals in the data set. This method of analysis has been previously demonstrated in NHS Direct research[36]. All statistical procedures were generated with SAS software, version 9.1 (SAS Institute, Cary, NC, USA).

Results

Telehealth received over 2 million calls during the study period of which 184 904 (9%) were for GI complaints addressed by selected guidelines. The NACRS database registered 17.5 million abstracts of which 34 499 (0.2%) were for the ICD-10-CA coded GI diagnoses. More patients in the 0-4 year age category (44%) visited the ED for their illness whereas Telehealth was contacted equally for the 0-4 year (40%) and 18-64 year (42%) groups. Only 6.4% of Telehealth calls and 7.4% of ED visits for GI complaints were for patients greater than 65 years old. (Table 4)

Vomiting, diarrhea and rectal bleeding guidelines were used most often by Telehealth to determine caller disposition. Adults aged 18-64 years reported an equal incidence of vomiting and diarrhea (35% and 37% respectively) and a 21% incidence of rectal bleeding. In the 0-4 age group symptoms of vomiting (59%) were more common than diarrhea (31%). The incidence of rectal bleeding in the pediatric population was negligible. The most frequently reported ICD-10-CA code was A08 (viral enteritis) accounting for 75% of ED discharges. (Figure 1) An additional 15% of ED visits were coded as A09 (diarrhea and gastroenteritis of presumed infectious origin). Diagnosis of specific foodborne illness was rare (3.5%) but if diagnosed was more likely to be in adult patients.

Two corresponding peaks for GI Telehealth calls and ED discharges in the data set occurred in January and March 2005. (Figure 2) The time-series analysis comparing data sets calculated the Spearman correlation coefficient at 0.90 ($p<0.0001$). One statistically significant correlation was found between the Telehealth and the NACRS GI

data at lag (weekly) 0 indicating increases in both series can occur simultaneously. (Table 5) The absence of a positive lag indicates changes in Telehealth GI call volume do not precede corresponding ED discharges for GI complaints.

Discussion

Prompt detection of bioterrorism is a primary concern for Public Health, emergency and security management organizations. To address the issues of delayed outbreak recognition and intervention inherent in traditional health surveillance methods, syndromic surveillance programs have been integrated into the health care system at the earliest points of access. These programs use real-time, existing data streams for prompt analysis and identification of infectious disease outbreaks[37]. Use of multiple, non-traditional data sources to enhance surveillance systems and increase specificity is supported in the literature[16-25,38]. Although Telehealth was not intended for surveillance, results from this study suggest integration of Telehealth data into a real-time surveillance system may be a complimentary tool for the detection of GI illness in Ontario.

Comparisons of Telehealth to NACRS data on GI illnesses show both curves are highly correlated. The time-series cross-correlogram demonstrated Telehealth data can document increases in GI calls simultaneously with, but not preceding, NACRS ED visits. NACRS data is based on physicians' diagnoses converted into ICD-10-CA codes at the conclusion of each patient visit. Telehealth syndrome guidelines are not equivalent to ICD-10-CA codes, however, Telehealth calls are potentially proxy measures for ED discharge diagnosis of communicable GI illness.

The success of a surveillance system depends on its simplicity, flexibility, data quality, acceptability, sensitivity, representativeness and timeliness[39]. Utility of the NACRS as a provincial surveillance tool is limited by the timeliness of data submission and analysis which may be delayed by months[31]. Analysis of discharge data before they are amalgamated in the NACRS database would require the manual searching of each individual hospital database. In contrast, Telehealth is high volume, universally accessible, available 24/7/365 and allows real-time electronic data collection using a centralized database[34]. These characteristics permit earlier detection of communicable GI illness despite the absence of a positive lag on statistical analysis.

GI illness resulting from intentional contamination of food or water is likely to affect a wide demographic. Telehealth receives a large volume of calls regarding pediatric patients and a marked deficiency in those over the age of 65. This inadequate representation of the elderly population may be explained by their hesitation to use or lack of awareness of the Telehealth program, or their preference for other points of access to health care[40]. Integrating Telehealth data into ED surveillance systems will allow a larger percentage of health care users to be monitored including patients not subject to conventional surveillance methods. Patients that do not seek medical care by a physician or receive laboratory confirmation of their illness and those directed by Telehealth to remain at home will be included in an integrated surveillance system. Formal infectious disease surveillance will also be extended to Northern Ontario, an area of widely dispersed populations that is traditionally underserviced by health care resources.

The majority of the NACRS ED visits were assigned to the A08 (viral enteritis) and A09 (diarrhea and gastroenteritis of presumed infectious origin) codes. This is in keeping with the nonspecific symptom profile of many bioterrorist pathogens. Although a constellation of symptoms may suggest a communicable disease process it is unlikely a specific pathogen would be diagnosed during the initial ED visit. Further, most physicians do not perform laboratory evaluation in uncomplicated cases of GI illness. The ICD-10-CA codes in this study are similar to those used by ESSENCE except for helminthic and mycotic disease which are unlikely to be used for bioterrorism and were excluded[41].

Real-time detection of a bioterrorist event allows rapid introduction of strategies to mitigate the associated mortality and morbidity. Because bioterrorism agents have short incubation periods (3-5 days) traditional surveillance methods are too slow to facilitate an effective response[29]. Early detection by Telehealth surveillance can limit spread of disease through rapid introduction of post exposure prophylaxis or treatment, allocation of health resources and implementation of public health measures[15]. Patterns of infectivity will depend on the agent and the source; widespread infection is expected for waterborne sources versus a more limited distribution of illness from a food delivery source. Once an outbreak is recognized, further spatial analysis and real-time geographic mapping of Telehealth data to corresponding public health units or water

distribution systems can facilitate targeted epidemiologic investigation and effective resource allocation. Conversely, during periods of increased security concerns, Telehealth surveillance can provide reassurance that an infectious disease outbreak is not occurring thereby allowing modification of aberration detection tools to lower thresholds for investigation of statistical alerts.

Limitations

This study relies on retrospective administrative data which have inherent weaknesses. Although data are provided by experienced physicians, nurses and health records staff, human error in coding or diagnosis is possible. The NACRS has effective filters for incomplete or inaccurate data, however, Telehealth does not. The forward sortation area field of the NACRS and the age and sex fields of the Telehealth data showed minimal missing values (data not shown). These data points permit geographical presentation of data and real-time spatial analysis, however, were not used in the time-series analysis so would not affect results. Selection bias may have been introduced by people that do not seek any form of medical attention but is likely of little significance in this study due to the universal access to health care for all Canadians. Conclusions of the study reflect only the 22 months of data and may not be representative of longer trends for GI illness.

Conclusions

Telehealth data can serve as proxy measures for ED discharge diagnosis data for GI illness in Ontario. This represents a novel use of Telehealth as a health surveillance tool. Integration of Telehealth Ontario data into real-time ED syndromic surveillance programs for GI illness can provide an early warning system for the detection of bioterrorist events.

Table 6-1: Centers of Disease Control and Prevention biological agent categories for disaster and public health preparedness

Biological Agent		***Disease***
Category A	*Variola major* ***Bacillus anthracis*** *Yersinia pestis* *Clostridium botulinum* *Francisella tularenis* *Filoviruses, Arenaviruses*	Smallpox Anthrax Plague Botulism Tularemia Viral Hemorrhagic Fevers
Category B	*Coxiella burnetii* *Brucella* species *Burkholderia mallei* *Burkholderia pseudomallei* Alphaviruses (VEE, EEE, WEE) *Rickettsia prowazekii* **Toxins** (ricin, staphylococcal enterotoxin B) *Chlamydia psittaci* **Food safety threats** (*Salmonella, E. coli 0157:H7)*[*] **Water safety threats** (*Vibrio cholerae*, *Cyptosporidium parvum)*[*]	Q fever Brucellosis Glanders Melioidosis Encephalitis Typhus fever Toxic syndromes Psittacosis Gastroenteritis Gastroenteritis
Category C	Newly emerging agents (Hantavirus, Nipah virus)	

VEE – Venezualan equine encephalitis; EEE – Eastern equine encephalitis; WEE – Western equine encephalitis

Bold= agents with potential to present as a gastrointestinal syndrome

* not an inclusive list

Table 6-2: Communicable gastrointestinal syndromes coded by hospital health coder post-discharge from ICD-10-CA classifications

ICD-10-CA Code*	***Code Description***
A00	Cholera
A01	Typhoid and Paratyphoid Fevers
A02	Other Salmonella Infections
A03	Shigellosis
A04	Other Bacterial Intestinal Infections
A05	Other Bacterial Foodborne Intoxications
A06	Amoebiasis
A07	Other Protozoal Intestinal Diseases
A08	Viral and Other Specified Intestinal Infections
A09	Diarrhea and Gastroenteritis of Presumed Infectious Origin
A22	Anthrax

* Includes any subcodes for each category listed

Table 6-3: Syndrome grouping of gastrointestinal illness with corresponding Telehealth Ontario guideline

Syndrome	***Telehealth Ontario Guideline***
Gastrointestinal	Diarrhea (Adult After Hours) Diarrhea (Pediatric After Hours) Stools – Blood In (Pediatric After Hours) Stools – Unusual Color (Pediatric After Hours) Stools – Unusual Color (Adult After Hours) Vomiting (Adult After Hours) Vomiting (Pediatric After Hours)

Table 6-4: Age distribution of the National Ambulatory Care Reporting System's (NACRS) emergency department visits and Telehealth Ontario calls for gastrointestinal illnesses in Ontario, Canada from June 2004 to March 2006

Age group (yrs)	*NACRS (n=34 499)*		*Telehealth (n=184 904)*	
	n	*%*	*n*	*%*
0-4	15 067	43.6	73 284	39.6
5-17	6 825	19.8	22 091	11.9
18-64	10 061	29.2	77 654	42.0
65+	2 546	7.4	11 875	6.4

Table 6-5: Schematic representation of cross correlations of residuals (weekly) for National Ambulatory Care Reporting System (NACRS) and Telehealth Ontario gastrointestinal data

Variable	***Lag***																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
NACRS	++	/	/	/	/	/	/	/	/	-	/	/	-	/	/	/	/	/	/	/	/
Telehealth	++	/	/	/	/	/	/	/	/	-	/	/	/	/	/	/	++	/	/	+	/

+ is > 2 standard error
- is < -2 standard error
/ is between

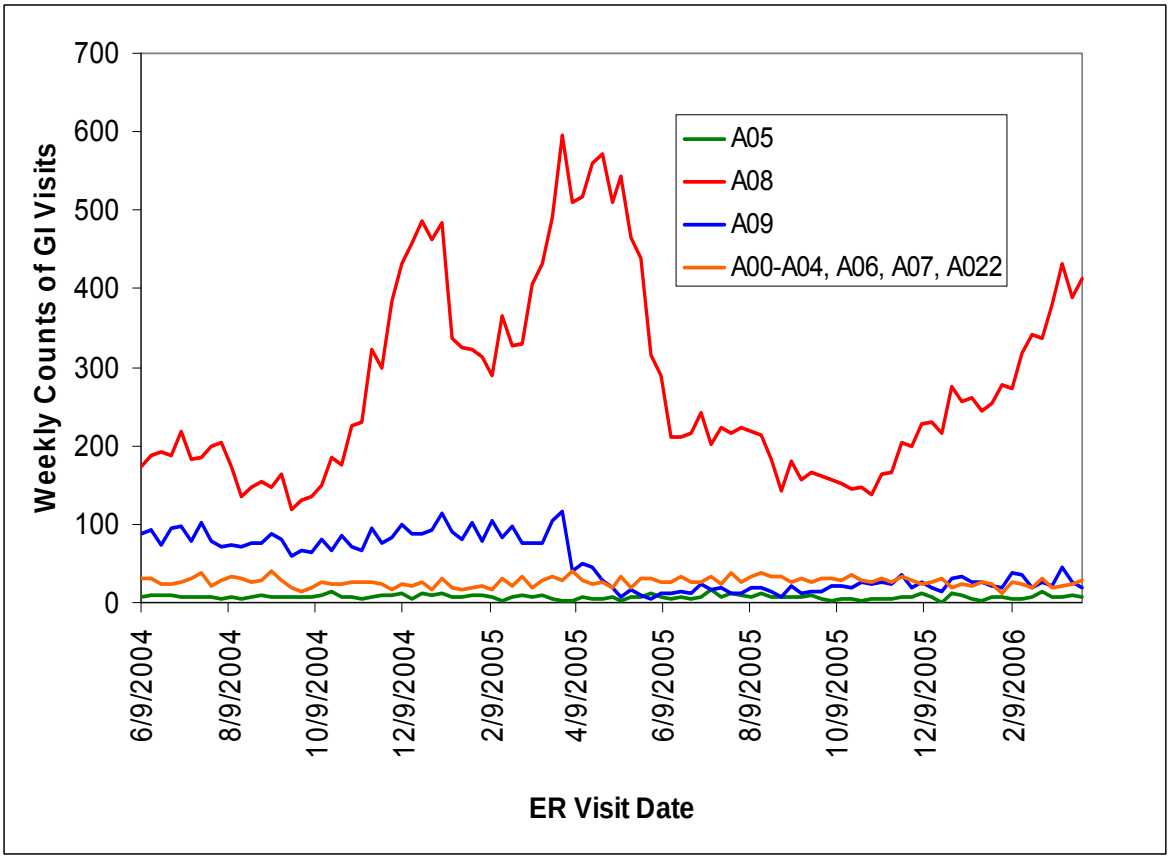
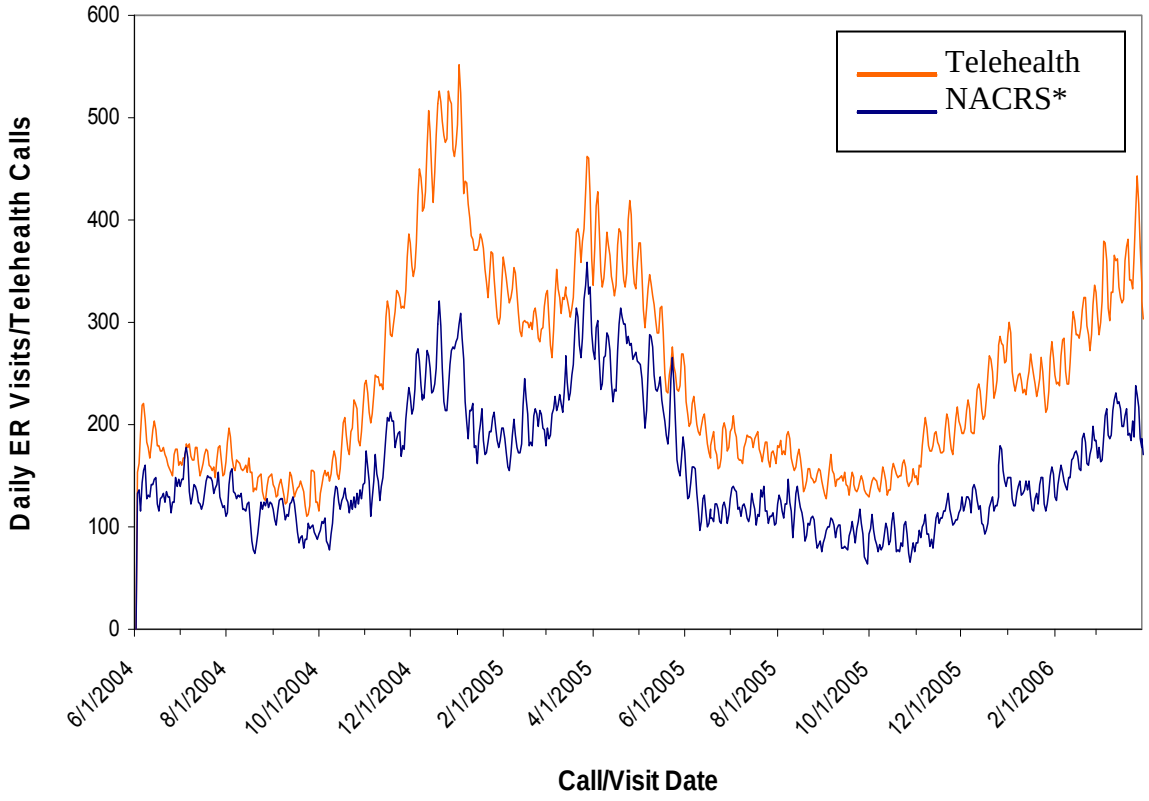


Figure 6-1: Breakdown of time-series for gastrointestinal International Classification of Diseases 10th revision, Canadian Enhancement (ICD-10-CA) codes, weekly – Ontario, Canada, June 2004 – March 2006



* NACRS data multiplied by a factor of 3

Figure 6-2: Telehealth Ontario (upper line) and the National Ambulatory Care Reporting System (lower line) time series for gastrointestinal illnesses, weekly – Ontario, Canada, June 2004 – March 2006

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