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Use of Ambulance Dispatch Data as an Early Warning System for Communitywide Influenzalike Illness, New York City

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ABSTRACT *In 1998, the New York City Department of Health and the Mayor's Office of Emergency Management began monitoring the volume of ambulance dispatch calls as a surveillance tool for biologic terrorism. We adapted statistical techniques designed to measure excess influenza mortality and applied them to outbreak detection using ambulance dispatch data. Since 1999, we have been performing serial daily regressions to determine the alarm threshold for the current day. In this article, we evaluate this approach by simulating a series of 2,200 daily regressions. In the influenza detection implementation of this model, there were 71 (3.2%) alarms at the 99% level. Of these alarms, 64 (90%) occurred shortly before or during a period of peak influenza in each of six influenza seasons. In the bioterrorism detection implementation of this methodology, after accounting for current influenza activity, there were 24 (1.1%) alarms at the 99% level. Two occurred during a large snowstorm, 1 is unexplained, and 21 occurred shortly before or during a period of peak influenza activity in each of six influenza seasons. Our findings suggest that this surveillance system is sensitive to communitywide respiratory outbreaks with relatively few false alarms. More work needs to be done to evaluate the sensitivity of this approach for detecting nonrespiratory illness and more localized outbreaks.*

KEYWORDS *Ambulance dispatch, Bioterrorism, Cyclical regression, Emergency medical services, Influenza surveillance, Syndromic surveillance, Time series.*

INTRODUCTION

The recent bioterrorist attacks associated with intentional release of *Bacillus anthracis* spores have underscored the need for enhanced public health surveillance systems to detect epidemics caused by biologic terrorism. Although education and improved communication among public health officials, clinicians, and laboratory technicians are important components of enhanced surveillance, surveillance for nonspecific prodromal symptoms through electronic administrative records might also be useful in the early detection of large-scale bioterrorist events. While many of the infections that cause the most concern,[1] such as anthrax, plague, smallpox, tularemia, and viral hemorrhagic fever, have distinct clinical characteristics and diagnostic criteria, the first signs of illness with these agents are likely to be nonspe-

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cific, with respiratory and constitutional symptoms similar to influenzalike illness (ILI). In 1998, the New York City Department of Health and the mayor's Office of Emergency Management began monitoring the volume of ambulance dispatch calls as a surveillance tool for biologic terrorism. The Department of Health has used annual influenza epidemics to evaluate the ability of this approach to detect communitywide respiratory illness. This report describes the results of this assessment.

METHODS

Data Sources

There are approximately 1 million medical calls to 911 in New York City every year. All calls are immediately categorized by a dispatcher into 1 of 52 broadly defined call types (e.g., emotionally disturbed person, cardiac, etc.) and entered into a computerized ambulance dispatch system at the New York City Fire Department Emergency Medical Services (EMS). Starting in May 1998, adult and pediatric asthma call types were added. Call types considered by the Department of Health as possibly consistent with ILI or pneumonia include respiratory distress, difficulty breathing, sick, and sick–pediatric and are referred to as ILI call types.

The New York City Department of Health obtained retrospective data on total ambulance dispatches and ILI call types from the fire department for 1993 through 1998. Prospective surveillance using daily facsimile transmission of summary data began in February 1999; daily electronic transmission began in March 2001. To compare the timing of increases in ambulance dispatches to influenza activity, weekly virus isolation data from World Health Organization (WHO) collaborating laboratories in New York City were obtained from the New York State Department of Health. Daily temperature data were obtained from the National Oceanic and Atmospheric Administration.

Statistical Analysis

Traditional methods of estimating excess mortality due to influenza[2–4] have used linear regression with sine and cosine coefficients to account for seasonal variability. To apply this cyclical regression model to outbreak detection using nonspecific administrative data, we implemented several modifications. First, to account partially for fluctuations in volume purely due to health-seeking behavior, the ratio of ILI call types to all call types (ILI rate) was treated as the outcome of interest. Second, additional regression terms were added to account further for day-of-week variability, holidays, and heat waves. Third, rather than excluding data from influenza epidemic weeks in the baseline,[4] independently ascertained data (laboratory influenza isolates) were used to control for the effects of influenza A and B on ambulance dispatches. Due to the large number of daily calls, the high frequency of ILI call types, and the normally distributed values of the ratios, in the interest of simplicity and ease of interpretation, linear regression (rather than Poisson regression) was used to model the ILI rate.

The base model was therefore linear regression of the EMS ILI rate on the following: (1) sine and cosine terms with annual periodicity; (2) linear and quadratic terms for secular trends over time; (3) dummy variables for day of week, holiday, and postholiday; (4) number of positive influenza A and B isolates reported by WHO collaborating laboratories by week's end; and (5) a heat variable equal to the cumulative number of degrees Fahrenheit by which the maximum temperature exceeded 90°F in the prior 3 days.

Since 1999, we have been performing serial daily regressions with up to 3 years of baseline data to determine the alarm threshold for the current day. Observations from the prior 2 weeks are deleted to avoid fitting the model on a slowly building outbreak, and the model is then projected forward for 2 weeks. An *alarm* is defined as a day when the observed ILI rate exceeded the expected upper confidence limit (e.g., a 99% alarm occurs when the observed value exceeds a 99% confidence limit).

Due to reporting delays, influenza isolation data are sometimes not available in real time. If the number of influenza isolates for the current day is set to missing, then the alarm threshold will not be raised to reflect current influenza activity. The system will therefore be sensitive to increases in respiratory illness due to influenza. This approach can be formalized as the influenza surveillance implementation of the model. If the number of influenza isolates for the current day is available and included, then the outbreak detection system is looking for respiratory illness above and beyond what is expected due to seasonality and influenza activity. This approach can be termed the bioterrorism surveillance implementation of the model.

In this article, we evaluate the two implementations of this model by simulating a series of daily regressions from September 1995 to April 1998, when the asthma call types were added. We then reproduce our analyses from September 1999 to January 2003 using a baseline that begins on May 1, 1998. Regression coefficients, expected values, and upper and lower confidence limits were extracted from each of 2,200 regressions. All analyses were performed using SAS statistical software (PROC REG, SAS, version 8.02, SAS Institute, Inc., Cary, NC).

RESULTS

The first regression of the series included data from January 1, 1993, through August 18, 1995. This regression model explained a large proportion of the daily variability in the ILI rate, as measured by an R squared of 76%. All terms in the model were significant at the .05 alpha level (Table). There are significant weekly changes in the ILI rate, with Saturdays having the lowest ratio and Mondays the highest (an average of 3.4% higher than Saturdays). This basic model was kept (while coefficients were allowed to vary) in serial daily regressions with up to 3 years of moving baseline.

Influenza Implementation

The ILI rate increased significantly with increased numbers of laboratory-confirmed influenza isolates, above and beyond the usual wintertime seasonal increase. The Figure graphically shows the results of the serial regressions for the influenza surveillance implementation of the model. The ILI rate for each day's EMS calls is plotted along with upper and lower confidence limits and the number of positive influenza A and B isolates. In the 2,200 days under analysis, there were 121 (5.5%) alarms at the 95% level, including 71 alarms at the 99% level. Of these alarms, 64 (90%) occurred shortly before or during a period of peak influenza, 2 occurred during a blizzard in 1996, and 5 are unexplained and likely due to chance. Each influenza season in 1995–1998 was associated with repeated alarms.

Prospective implementation since 1999 resulted in detection of all three annual influenza epidemics, generally 2 to 3 weeks prior to notification of widespread influenza activity from traditional influenza surveillance systems. The first 95% alarm in 2001–2002 occurred on December 29, a time when influenza activity was

TABLE. Regression of influenzalike illness rate (Emergency Medical Services), September 1, 1995

Term	Parameter estimate	p value
Date	−0.07%	0.001
Date-Squared	0.00%	0.001
Cos	2.89%	<.0001
Sine	0.56%	<.0001
Saturday		ref
Sunday	1.98%	<.0001
Monday	3.43%	<.0001
Tuesday	2.68%	<.0001
Wednesday	2.51%	<.0001
Thursday	2.00%	<.0001
Friday	0.66%	0.001
Holiday	−1.73%	0.0002
Postholiday	0.99%	0.03
Influenza A	0.13%	<.0001
Influenza B	0.08%	<.0001
Heat wave	0.04%	0.01

Date is the number of days since January 1, 1960; Cos is cos(date*(2*pi)/365.25); Sine is sine(date*(2*pi)/365.25); holidays include Christmas, New Year's, Memorial Day, Fourth of July, and Labor Day; Influenza A and B are the number of positive isolates reported by week's end by World Health Organization reference laboratories in New York City; Heat wave is the number of degrees Fahrenheit that the maximum temperature in the prior 3 days exceeded 90°F.

estimated as only sporadic. Repeated alarms at the 95% and 99% level occurred beginning January 2. Outreach by New York City Department of Health staff to emergency departments, infection control practitioners, intensive care units, and clinical laboratories found no evidence of illness suspicious for biologic terrorism. Updated results from specimens received at WHO collaborating laboratories in New York City in the week ending December 29 became available on January 11 and revealed 11 positive influenza A isolates. At approximately the same time, several nosocomial influenza outbreaks were reported, and pneumonia and influenza deaths for the week ending January 11 were found to be significantly elevated, establishing the onset of widespread influenza activity in New York City.

Bioterrorism Implementation

In the bioterrorism application of this methodology presented here, the goal is to detect respiratory illness in excess of what is expected due to seasonality and influenza. By controlling for current influenza activity, the alarm thresholds can be increased during influenza season, and alarms are minimized, although not eliminated (see B in the Figure). In 2,200 days under analysis, there were 45 (2.05%) alarms at the 95% level, including 24 alarms at the 99% level. Of these 24 alarms, 21

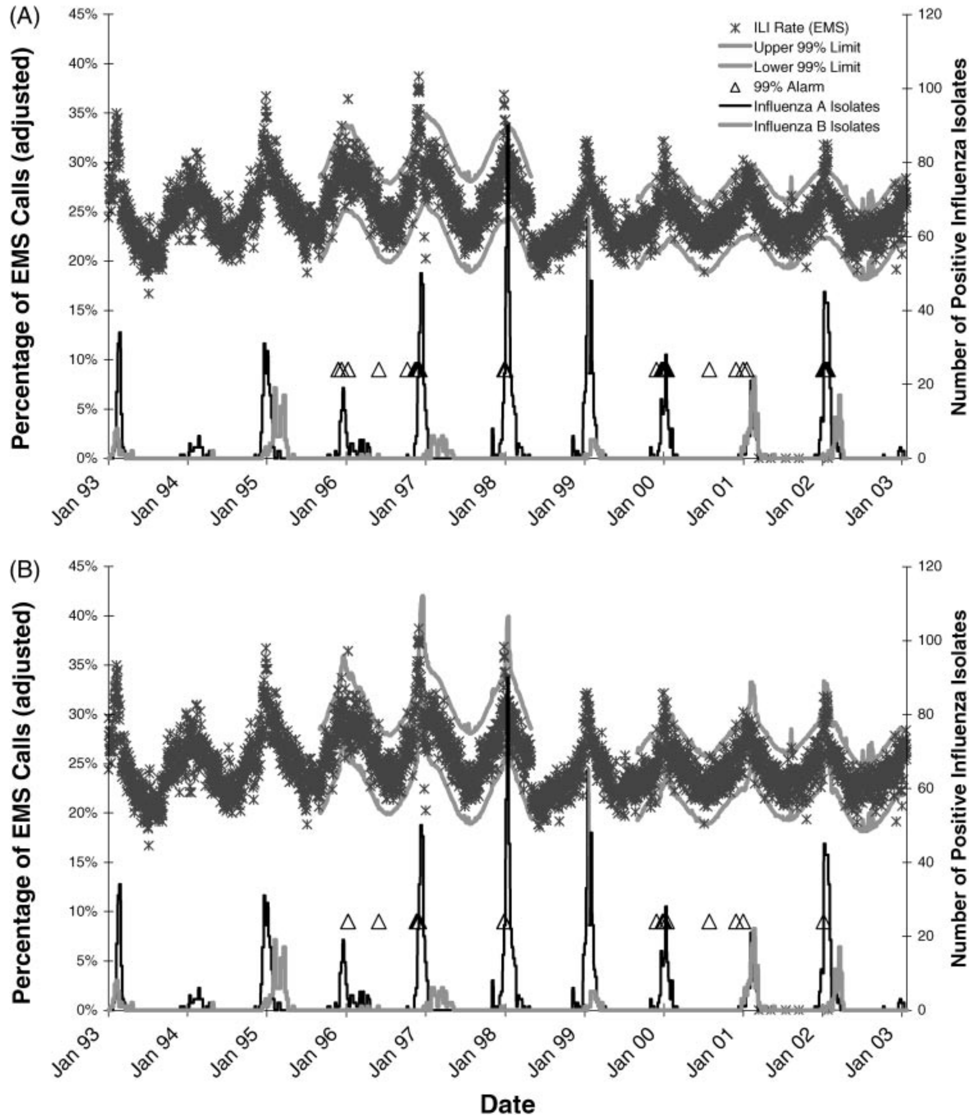

FIGURE. Emergency Medical Services respiratory calls and influenza isolates, by day, 1993 to 2003, New York City. The left-hand *y* axis represents the percentage of EMS calls that are in one of four selected call types (respiratory distress, difficulty breathing, sick, and sick–pediatric) (influenza-like ilness [ILI] rate). Each asterisk represents the value for 1 day. The gray lines above and below represent 99% confidence limits. The triangles represent days when the observed value exceeded the 99% upper confidence limit. The right-hand *y* axis represents the number of positive influenza isolates reported by week's end from viral reference laboratories in New York City. The *x* axis is the date, from January 1, 1993, to January 23, 2003. (A) Influenza outbreak detection implementation. The 99% alarm thresholds do not account for current influenza activity. (B) Bioterrorism detection implementation. The 99% alarm thresholds account for current influenza activity.

(88%) occurred shortly before or during a period of peak influenza activity in each of six influenza seasons, 2 occurred during a blizzard, and 1 is unexplained.

DISCUSSION

This article describes an evaluation of a surveillance methodology based on electronic records of ambulance dispatches to detect communitywide respiratory outbreaks. This syndromic surveillance approach successfully identified the expected annual epidemics of influenza in simulated serial daily analyses from 1994 to 1998 and prospectively from 1999 to 2002. The rate of alarms was sustainable for public health response, with only five unexplained alarms at the 99% level in 2,200 days of surveillance.

Our results suggest that this approach might be able to detect other large communitywide respiratory outbreaks, including those caused by biologic terrorism. Some researchers have identified outbreak detection during influenza season as a key challenge to syndromic surveillance systems.[5] By controlling for current influenza activity, the alarm thresholds can be increased during influenza season, and alarms are minimized, while maintaining sensitivity for outbreaks due to other causes. This bioterrorism detection methodology relies on timely information from traditional influenza surveillance. Delays in diagnosis and reporting of influenza isolates can result in false alarms due to influenza.

There are several weaknesses inherent in this and other syndromic surveillance systems. These systems are dependent on the availability of populationwide electronic data that are routinely collected, are timely, and can be categorized into syndromes. In general, the systems also require a large number of nonspecific illnesses to occur before an event is detected. Finally, unlike traditional surveillance, syndromic surveillance requires rapid investigations to determine the etiology of the detected aberration. Any signals from syndromic surveillance systems must be investigated quickly to characterize these potential outbreaks and rule out the possibility of biologic terrorism or a naturally occurring outbreak.

The particular statistical methodology described here could be further refined. Some of the recent advances in influenza surveillance,[6] including use of Poisson regression and inclusion of other viral respiratory agents in the regression model, could be improvements over the model presented here.

New York City public health officials are working toward developing, implementing, and evaluating additional complementary surveillance systems based on preexisting electronic records. More work needs to be done to evaluate the sensitivity of these systems for detecting nonrespiratory illness and more localized outbreaks. To improve the sensitivity and specificity of these systems further, analytic methods that can detect spatial as well as temporal clustering of syndromic events must be developed and validated.

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