Using encounters versus episodes in syndromic surveillance

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ABSTRACT

Background Automated electronic medical records may be useful for syndromic surveillance to quickly detect infectious disease outbreaks. Some syndromic surveillance systems include every encounter in the analysis, whereas others exclude individuals' repeat encounters within the same syndrome occurring within a short period of time, with the rationale that these represent follow-up visits rather than new episodes of illness.

Methods We evaluate the effect of keeping all encounters as compared with removing repeat encounters. Using the prospective space–time permutation scan statistic, we performed daily analyses on all encounters versus on episodes defined as encounters new within 2, 6 or 12 weeks. Data were taken from a Massachusetts Health Maintenance Organization (HMO) for the calendar year 1999 for four different syndromes.

Results We found extensive disagreement in the number of signals detected: 70, 68, 21 and 15 signals when using all encounters versus 15–20, 3, 4–5 and 0 signals when using only new episodes for lower respiratory, lower gastrointestinal, upper gastrointestinal and neurologic syndromes, respectively.

Conclusion Using all encounters in syndromic surveillance may not only create too many signals but may also miss some signals by masking the anomalies generated by actual episodes. However, it is also possible to miss signals when using episodes.

Keywords gastrointestinal, lower respiratory, neurologic, space–time surveillance

Introduction

In recent years, public health authorities, academic investigators and profit-seeking companies have developed systems that monitor routine health-care contacts and attempt to discern patterns that herald emerging public health needs.^{1–11} The health-care contacts so considered range from emergency room visits^{12–14} to outpatient visits,^{3–5,15} to telephone calls,^{6,16,17} to over-the-counter drug sales,^{18,19} to absenteeism data.^{20,21} A typical system will count the daily number of visits that are classified as belonging to a specific syndrome and provide an assessment of whether there have been an ordinary or extraordinarily large number of visits during the last few days. Sufficient evidence of the latter might prompt action by public health authorities.

Often ignored is the fact that many health-care contacts are repeat visits for the same complaint.^{3–5} For example, a patient in an outpatient setting may return 2 weeks after an initial contact, seeking further relief for the same problem. Sometimes these repeat visits may have different diagnoses; for instance, a first visit may be assigned a diagnosis of 'bronchitis' and the second 'pneumonia'. Many syndromic

surveillance systems lack the capability to distinguish repeat visits within the same syndrome, or can do so only at great expense. From a statistical perspective, the repeat visits are not independent, but are correlated within individual. However, most commonly used statistical alerting methods assume that the visits are uncorrelated.^{22–24} While some systems do remove repeat visits,^{9,10,15} there is no evidence regarding the effect of keeping all contacts as compared with removing repeat contacts.

When repeat encounters are included in the data, the assumption of independence is violated. Since the same person may seek medical care multiple times for the same disease episode that would lead to over-dispersion of the data, which in turn would generate more statistically significant signals than one would expect based on the nominal

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alpha level. There are many data sets where only encounters are available, and where it is either impossible or expensive to obtain episode data. From a practical point of view, the important question is then whether it matters whether we use encounters or episodes. One way to try to evaluate that is to compare the signals obtained when doing an analysis based on all encounters versus an analysis based on episodes defined in various ways. If the number and nature of the signals are similar, that is evidence that it is not of critical importance to use episodes rather than encounters and we may be safe to use encounter data without having to go through the extra effort of obtaining episode data. However, if there is a substantial discrepancy in the number of the signals in such a way that the encounter analysis generates much greater number of signals, it may indicate that some of the signals are false positives.

We undertook the current study to evaluate the effects of various definitions of repeat visits, including treating every contact as if it were a new complaint (the usual practice) as well as excluding repeat visits with diagnoses in the same syndrome class within a range of time spans. We used data from an Health Maintenance Organization (HMO) health plan covering eastern Massachusetts and applied the space-time permutation scan statistic as a test statistic.²⁵ The results should help surveillance system designers determine whether the additional cost of developing the ability to exclude repeat visits is worth any potential benefit gained.

Methods

Data sources

We used data collected on the visits of members of an HMO and physician practice in eastern Massachusetts. The data have been described previously^{9,15} and used in the National Bioterrorism Syndromic Surveillance Demonstration Program.¹⁰ For the years of 1996 through 1999, the data include approximately 250 000 health plan members in greater Boston area.⁹ Briefly, the data include all encounters with ICD-9 codes²⁶ included in nine syndromes created to reflect potential bioterrorism agents.³ The data used here are from the period 1 January 1998 through 31 December 1999. In this article, we present surveillance-like analyses of the calendar year of 1999 (1998 was used as a baseline year). We repeated our analyses, using data from the beginning of the year through each day in 1999 and report the resulting signals for surveillance of that day. We used four syndromes: lower respiratory infection (LoRI), lower gastrointestinal (LoGI), upper gastrointestinal (UGI) and neurologic. The details regarding which ICD-9 codes are included in which syndromes are discussed elsewhere.³

Definition of encounters and episodes

Encounters comprise records of all visits as well as telephone calls that clinicians chose to record. A patient may have multiple encounters on the same day. Episodes are defined as encounters new within x weeks, i.e. encounters occurring at least x weeks after the most recent encounter of the same syndrome. We considered encounters new within 2, 6 and 12 weeks. Every patient has the first encounter on possibly different dates. The first encounter is always kept as the first episode. Then, the next episodes are determined using the x -week rule from the first episode. Using the 2-week rule, for example, if a patient first visited a health care on 1 January 1998, then any visits before 15 January 1998 are not considered as new episodes for the patient and the encounters are removed. The second episode is the encounter first occurred after 15 January 1998, the third one is the encounter first occurred after 2 weeks from the second episode and so on. The 6- and 12-week rules apply in the same way. More encounters are removed for 6-week rule episodes than for 2-week rule and even more are removed for 12-week rule episodes than for 6-week rule. For reference, in the National Bioterrorism Syndromic Surveillance Demonstration Program,¹⁰ only episodes defined as encounters new within 6 weeks are counted.

Statistical methods

We used the prospective space-time permutation scan statistic, which was developed for the early detection of disease outbreaks and is especially useful when we have only the number of cases and no population-at-risk information.²⁵ Using a cylindrical window with the base representing space and the height representing time, the space-time permutation scan statistic results from a scan of a wide range of possible areas and time periods. In prospective analyses, the temporal window must include the current time point of surveillance. For each syndrome, we performed daily analyses on all encounters and on encounters new within 2, 6 and 12 weeks, respectively, for the year 1999 with a 1-year baseline. Individual counts of encounters/episodes were aggregated into census tracts. We allowed the temporal scanning window to be anywhere in the range of 1–7 days, to detect a single-day outbreak as well as abnormalities which might not be picked up on a single day but would become significant after several days of accumulation. The maximum spatial scanning window was set to 20% of the population, which means we searched for clusters in any size between 0 and 20% of the population. Our analyses were adjusted for purely spatial and purely temporal variation as well as for space by day-of-week interaction. Purely spatial or purely temporal clusters were not

to be detected as significant clusters and anomaly simply due to space by day-of-week interaction was also not to be picked up. The space–time permutation statistic automatically adjusts for any purely spatial and purely temporal variation and the space by day-of-week interaction was adjusted by a stratified random permutation procedure.²⁵ Holidays were treated as Sundays since health-care hours on holidays are expected to be similar to those on Sundays and hence a similar pattern of encounters is expected. We define a signal as an event with *P*-value less than or equal to 0.0027, which is equivalent to an unusual event with recurrence interval (RI) of once every year or less often. RI is computed as the reciprocal of a *P*-value for daily analyses and interpreted as the number of surveillance days required to expect an event as unusual as the one observed to occur exactly once by chance.²⁷ A larger value of RI indicates a more alarming and unusual event.²⁴ Calculation was done using the free SaTScan software version 5.1.²⁸

Results

The number of patients and counts of all encounters and encounters new within 1, 2, 4, 6, 9 and 12 weeks (episodes) for the year 1999 for each syndrome are presented in

Table 1, with the number of signals detected only for all encounters and encounters new within 2, 6 and 12 weeks, on which the analyses were performed. A total of 23 712 patients had 37 421 LoRI, 9997 patients had 15 946 LoGI, 6127 patients had 8099 UGI and 202 patients had 293 neurologic syndrome encounters. Even by the 1-week rule, encounter counts drop by 11–20% while the number of patients does not decrease much. The rate of decrease in the encounter counts slows as the time interval for defining episodes increases. The percentages for the number of episodes compared with all encounters for LoGI syndrome are a little lower than for LoRI syndrome, but those for UGI and neurologic syndrome are a little higher.

For LoRI, 70 signals were detected when using all encounters versus 20, 15 and 20 signals when using encounters new within 2, 6 and 12 weeks, respectively. Among all the signals detected using encounters (70 signals) and episodes (20, 15 and 20 signals), 12 signals are common to both encounters and episodes of any description (episodes defined using 2-, 6- and 12-week rule). Considering signals on consecutive days and contiguous areas as one signal, 5 signals of 12 are distinct common signals. This is clearer in Fig. 1, which presents RIs in days for the signals detected

Table 1 Number of encounters and signals detected^a for the year 1999 for each syndrome

	All encounters	Episodes: encounters new within					
		1 week	2 weeks	4 weeks	6 weeks	9 weeks	12 weeks
Syndrome = LoRI							
Number of patients	23 712	23 692	23 652	23 579	23 495	23 353	23 207
Number of encounters/episodes	37 421	31 188	29 031	27 329	26 522	25 701	25 118
Percentage of all encounters	100	83	78	73	71	69	67
Number of signals ^a	70		20		15		20
Syndrome = LoGI							
Number of patients	9997	9988	9979	9960	9932	9883	9826
Number of encounters/episodes	15 946	12 752	11 930	11 288	10 976	10 670	10 438
Percentage of all encounters	100	80	75	71	69	67	65
Number of signals ^a	68		3		3		3
Syndrome = UGI							
Number of patients	6127	6121	6120	6109	6091	6070	6040
Number of encounters/episodes	8099	7136	6928	6695	6571	6446	6333
Percentage of all encounters	100	88	86	83	81	80	78
Number of signals ^a	21		4		5		5
Syndrome = neurologic							
Number of patients	202	202	201	201	201	201	200
Number of encounters/episodes	293	260	243	231	226	213	204
Percentage of all encounters	100	89	83	79	77	73	69
Number of signals ^a	15		0		0		0

^aNumber of signals detected is shown only for all encounters and encounters new within 2, 6 and 12 weeks, on which the analyses were performed.

Fig. 1 RI (in days) for the signals detected when using all encounters (A) versus encounters new within 2 (2), 6 (6) and 12 (T) weeks for each syndrome; vertical lines were drawn on the dates of common signals.

when using all encounters (A), encounters new within 2 (2), 6 (6) and 12 weeks (T) for each syndrome.

Figure 1 shows how many signals were detected and when they were detected using all encounters/episodes in the year 1999 for each syndrome and how strong the signals are. The vertical lines were drawn on the dates of the common signals using all encounters and episodes of any description for LoRI and LoGI, and on the date of the common signals using episodes for UGI. For the common signals on consecutive days, the line was drawn only on the first day of signal.

For LoGI syndrome, 68 signals were detected when using all encounters whereas only 3 signals were detected when using episodes. Two signals detected on 5 April and 25 August are common (Fig. 1). For UGI syndrome, 21 signals were detected when using all encounters versus 4 or 5 signals when using episodes. There is no common signal detected. The vertical line drawn on 8 November for UGI in Fig. 1 indicates a common signal detected using episodes of any description, which was not detected using all encounters. For neurologic syndrome, 15 signals were detected when using all encounters and no signals when using episodes of any description.

For UGI syndrome, even though there are no common signals detected using both encounters and episodes, four to five signals detected when using encounters new within 2, 6 and 12 weeks are basically the same. That is, the same signals were detected from the analyses using episodes of any description, but not using all encounters. Those signals that were first detected on 8 November lasted 4 or 5 successive days including the same start date of time period and the same geographic area, and are essentially one signal. The cluster information for the signals is presented in Table 2 and the geographic locations of the clusters in Fig. 2. For a comparison purpose, we include information for the most likely clusters from the analyses using all encounters on the same dates, although the clusters were not signals (RI < 1 year). The most likely clusters from the encounter analysis on 8, 9 and 12 November include the same time period and the same area (Cluster A) as the signals from the episode analysis. The observed counts in Cluster A on each of 8, 9 and 12 November are the same when using episodes or all encounters, which means that all the observations in Cluster A may represent new episodes (not repeat encounters) but

Table 2 Clusters information for the signals detected only from the analyses using episodes for UGI syndrome

	Obs	Exp	RI	Time period	Number of tracts	Cluster
8 November 1999						
All	15	3.3	0.5Y	6–8 November	17	A
2 weeks	15	2.9	2.7Y	6–8 November	17	A
6 weeks	15	2.9	2.3Y	6–8 November	17	A
12 weeks	15	2.8	6.9Y	6–8 November	17	A
9 November 1999						
All	17	4.2	0.5Y	6–9 November	17	A
2 weeks	17	3.6	4.6Y	6–9 November	17	A
6 weeks	17	3.5	3.9Y	6–9 November	17	A
12 weeks	17	3.4	6.9Y	6–9 November	17	A
10 November 1999						
All	5	0.2	0.9Y	4–10 November	1	B
2 weeks	19	4.4	2.7Y	6–10 November	17	A
6 weeks	19	4.3	5.5Y	6–10 November	17	A
12 weeks	19	4.2	13.7Y	6–10 November	17	A
11 November 1999						
All	24	8.0	0.2Y	5–11 November	23	C
2 weeks	20	5.1	1.8Y	6–11 November	17	A
6 weeks	20	5.1	2.7Y	6–11 November	17	A
12 weeks	20	4.8	9.1Y	6–11 November	17	A
12 November 1999						
All	21	7.1	0.1Y	6–12 November	17	A
2 weeks	21	6.0	0.7Y	6–12 November	17	A
6 weeks	21	5.9	1.4Y	6–12 November	17	A
12 weeks	21	5.6	2.5Y	6–12 November	17	A

Obs, observed count; Exp, expected count; Y, years.

cannot be picked up as unusual events in the model of all encounters. On the contrary, Table 3 shows the cluster information for the strongest signals when using all encounters, which were detected on 8 and 9 October, and the most likely clusters when using episodes on the same dates. Even though the most likely clusters from the episode analysis include the same time period and the same area (Cluster D), the observed counts of episodes drops by 3 (38–42%) from encounters. It seems that the occurrence on 8 and 9 October is not an unusual event any more after removing some repeat encounters. In fact, seven observed counts on 8 October for all encounters were from four patients with one patient having three encounters on 2 successive days, one patient having two encounters on 2 successive days and two patients having one encounter each. Also, eight counts on 9 October were from the same four patients on 8 October and one additional patient with one encounter. While it is not totally unexpected that signals detected when

Fig. 2 Cluster locations and sizes for the signals presented in Tables 2 and 3.

Table 3 Cluster information for the strongest signals detected from analyses using all encounters for UGI syndrome

	Obs	Exp	RI	Time period	Number of tracts	Cluster
8 October 1999						
All	7	0.3	27.4Y	6–8 October	2	D
2 weeks	4	0.2	0.04Y	6–8 October	2	D
6 weeks	4	0.2	0.04Y	6–8 October	2	D
12 weeks	4	0.2	0.04Y	6–8 October	2	D
9 October 1999						
All	8	0.3	27.4Y	6–9 October	2	D
2 weeks	5	0.2	0.4Y	6–9 October	2	D
6 weeks	5	0.2	0.4Y	6–9 October	2	D
12 weeks	5	0.2	0.4Y	6–9 October	2	D

Obs, observed count; Exp, expected count; Y, years.

using all encounters would disappear when using episodes since some records had been removed, it is noteworthy that we could miss signals by using all encounters, which can be detected using episodes. Removing repeat encounters does not necessarily result in loss of power for detecting signals, but rather it could improve the ability to detect signals.

Discussion

Main findings

We have conducted daily analyses on all encounters versus episodes (encounters new within 2, 6 or 12 weeks) to detect

outbreaks for four different syndromes and found a significant disagreement in the number of signals detected between using all encounters and using episodes. For LoRI syndrome, 70 signals were detected when using all encounters versus 15–20 when using episodes. Seventy signals a year seem too many compared with 15 or 20 signals. Similarly, 68 signals a year when using all encounters for LoGI syndrome appear to be too many compared to 3 signals when using episodes. For UGI syndrome, there are 21 signals detected when using encounters, but they are still many compared with 4 or 5 signals when using episodes. Neurologic syndrome occurs rather rarely (0–8 encounters a day) than the other syndromes. Still, 15 signals when using encounters versus 0 signal when using episodes is a considerable difference.

What is already known on this topic

The ability of a syndromic surveillance system to reliably detect an outbreak depends on the timely capture and processing of the data, the quality of the data and the detection methods.²⁹ Data quality is assessed based on representativeness of the population covered by the system, completeness of data capture and reliability of data captured over time.³⁰ However, a specific attention to the effect of removing repeat encounters compared with keeping all encounters has not been given.

What this study adds

Based on the results from this study, including all encounters in the analysis for syndromic surveillance may create too many signals and hence it would make it impossible to investigate all the signals detected. While we do not know for sure, many of those signals might be false alarms and too many false alerts would cause unnecessary costs and desensitization to true events. Not only might we find too many alerts by using all encounters, the results show that we could miss signals as well, which would make the surveillance system unreliable. It is also true, however, that we may find alerts using all encounters that would not be detected using only episodes.

Limitation of this study

We do not have information on whether there were real outbreaks of the syndromes included in this study for the year 1999 in the study area, and hence we do not know what the true signals are for this particular data set. It might be possible to perform analyses where we validate the encounter and episode analyses using a specific set of outbreaks, for example, if there was a collection of LoGI outbreaks (e.g.

from the state health department) in a certain area over time, then we could compare the episode and encounter analyses in their ability to detect these outbreaks.

Although we have substantially different results when using all encounters versus when using episodes, there seems to be little difference using among encounters new within 2, 6 and 12 weeks. The signals detected when using encounters new within 2, 6 or 12 weeks are almost identical in terms of number of signals, dates detected and locations of the most likely clusters. It is difficult to say which is clearly better than the others and it may require further investigation. It could depend on syndromes and data sources.

The results may or may not be the same for other data sources. For example, over-the-counter drug sales patterns or absenteeism data are more likely to have similar results than emergency department visit records, as a patient is not expected to visit the ED again for further relief as much as a patient visits an ambulatory care, seeks over-the-counter drugs or misses work or school. A different definition of episodes may be used for different data sources. A thorough evaluation of the effect of keeping all encounters versus removing repeat encounters for other data sources has not been done.

By using episodes we do not use all information. A person with multiple visits may be more severely affected than one with a single visit. If multiple encounters are included, some other way than simply treating them the same as a new episode may be considered. However, this kind of information may not be tractable enough to be incorporated into statistical models, and it is not clear how much would be gained from it.

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