Assessing the Effectiveness of the Early Aberration Reporting System (EARS) with Application to Bioterrorism

LT Katie Hagen
DTRA Briefing
16 November 2010
Early Aberration Reporting System (EARS)

– Originally designed to monitor for bioterrorism
– Now used by various state and local public health departments for routine health surveillance
Monterey County Daily Observational and Situational Evaluation (DOSE) Report
Tuesday, November 9, 2010 5:33 PM

This is a report of surveillance activities from the Monterey County Health Department’s Public Health Bureau.

Alert Levels: See below specifications for each indicator.

- Low
- Elevated
- High
- Severe

Action Items: The number of deaths reported for 11/06 were at the ELEVATED alert level. The number of calls to Poison Control on 11/06 were at the ELEVATED alert level. Coastal temperatures will be at the ELEVATED alert level for 11/11 and 11/12 for seasonal low temperatures. All other indicators were at LOW alert levels.

ED Census and Clinic Services Census:

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
<th>11/05/10</th>
<th>11/06/10</th>
<th>11/07/10</th>
<th>11/08/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>No alert flags on the previous day</td>
<td>254</td>
<td>222</td>
<td>267</td>
<td>289</td>
</tr>
<tr>
<td>Yellow</td>
<td>One alert flag on the previous day</td>
<td>575</td>
<td>Closed</td>
<td>Closed</td>
<td>723</td>
</tr>
<tr>
<td>Orange</td>
<td>Two consecutive days of the same type of flag</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red</td>
<td>Three consecutive days of the same type of flag</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note that the hospital ED aggregate and syndromic surveillance only includes data from facilities providing information for the reported days.

Syndromic Surveillance: County hospital aggregate [# of patients]

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
<th>11/05/10</th>
<th>11/06/10</th>
<th>11/07/10</th>
<th>11/08/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>No alert flags on the previous day</td>
<td>52</td>
<td>41</td>
<td>52</td>
<td>56</td>
</tr>
<tr>
<td>Yellow</td>
<td>One alert flag on the previous day</td>
<td>7</td>
<td>8</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Orange</td>
<td>Two consecutive days of the same type of flag</td>
<td>14</td>
<td>8</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Red</td>
<td>Three consecutive days of the same type of flag</td>
<td>28</td>
<td>24</td>
<td>38</td>
<td>30</td>
</tr>
</tbody>
</table>

Deaths reported through EDRS: Pulled by date of death, 6:10 PM 11/09/10

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
<th>11/05/10</th>
<th>11/06/10</th>
<th>11/07/10</th>
<th>11/08/10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>≤ 1 Standard deviations (over 6 mth avg)</td>
<td>10</td>
<td>11</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>
Problem Importance

Bioterrorism
- National security
- Loss of life
- Economic impacts
- Agricultural
- Way of life
Problem

- Was EARS able to “signal” prior to H1N1 epidemic?
- How can EARS be improved for detecting future epidemics/outbreaks?
EARS Logic

Ex: Alternative Flu Definitions

Base Case (CDC)
“sore throat” or
“cold” or
“cough”

Expanded (MCHD)
“cold” or
“cough” or
“fever” or
“chills” or
“muscle pain” or
“headache” or
“flu” and not “shot”

Restricted (MCHD)
“fever” and “cough” or
“fever” and “sore throat” or
“fever” and “cough” and
“sore throat” or
“flu” and not “shot”
153,696 total records

Logic

Flu Counts

Base Case

9,093 total "flu"

Expanded

5,154 added
291 deleted
13,956 total "flu" (53% ↑)

Restricted

51 added
8,410 deleted
734 total "flu" (92% ↓)

Detection Algorithms
EARS Detection Methods

Thresholds:

\[ C_1(t) = \frac{Y(t) - \overline{Y}_1(t)}{S_1(t)} \]

\[ C_2(t) = \frac{Y(t) - \overline{Y}_3(t)}{S_3(t)} \]

\[ C_3(t) = \sum_{j=t}^{t-2} \max[0, C_2(j) - 1] \]

-9, -8, -7, -6, -5, -4, -3, -2, -1, t

\[ C_1(t) > 3 \]

\[ C_2(t) > 3 \]

\[ C_3(t) > 2 \]
Alternate Detection Methods

Cumulative Sum (CUSUM):

First, we modeled the systematic effects of the biosurveillance data (Mon – Fri)

\[ Y_i = \beta_0 + \beta_1 \times (i - t + n) + \beta_2 I_{Mon} + \beta_3 I_{Tues} + \beta_4 I_{Wed} + \beta_5 I_{Thurs} + \epsilon \]

where, \( t \) = day and \( n \) = baseline period for \( i = t, \ldots, t-n+1 \), \( \beta_0 \) is the intercept term, \( \beta_1 \) is the slope, the Is are indicator functions (\( I = 1 \) on the relevant day of the week and \( I = 0 \) otherwise) and \( \epsilon \) is the error term to account for random variability.

Next, we estimated the predicted count for the current day \( (t+1) \)

\[ \hat{Y}_{t+1} = \hat{\beta}_0(t) + \hat{\beta}_1(t) \times (n + 1) + \hat{\beta}_j(t) \]

where \( \hat{\beta}_0(t), \hat{\beta}_1(t) \) and \( \hat{\beta}_j(t) \) are the estimated model coefficients from the regression fit at time \( t \), and where \( \hat{\beta}_j(t) \) is the relevant estimated day-of-the-week coefficient.

Thirdly, we calculated the standardized prediction error at time \( t+1 \)

\[ \Delta_{t+1} = Y_{t+1} - \hat{Y}_{t+1} \]
\[ \hat{\sigma}_t = \sum_{i=t}^{t-m-1} (\Delta_i - \overline{\Delta}_i)^2 \]
\[ Z_{t+1} = \Delta_{t+1} / \hat{\sigma}_t \]

The CUSUM statistic thus became:

\[ C_{t+1} = \max [0, C_t + Z_{t+1} - k] \]

where \( k = \frac{\delta}{2\sigma} = \frac{\sigma |\mu_1 - \mu_s|}{2} \) and \( \mu_1 \) is the mean shift that is desired to be detected quickly.
# Alternate Detection Methods

## Cumulative Sum (CUSUM):

<table>
<thead>
<tr>
<th>Type</th>
<th>Label</th>
<th>ATFS</th>
<th>k</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Aggressive&quot;</td>
<td>CUSUM 1</td>
<td>5</td>
<td>0.5</td>
<td>0.365</td>
</tr>
<tr>
<td>&quot;Routine&quot;</td>
<td>CUSUM 2</td>
<td>20</td>
<td>1</td>
<td>0.695</td>
</tr>
<tr>
<td>&quot;Extended&quot;</td>
<td>CUSUM 3</td>
<td>60</td>
<td>1</td>
<td>1.2</td>
</tr>
</tbody>
</table>
Original Logic (Base Case)

ILI Definition:
“sore throat” or
“cold” or
“cough”
ILI Definition:
“cold” or
“cough” or
“fever” or
“chills” or
“muscle pain” or
“headache” or
“flu” and not “shot”
ILI Definition:
“fever” and “cough” or “fever” and “sore throat” or “fever” and “cough” and “sore throat” or “flu” and not “shot”
Was EARS able to “signal” prior to H1N1 epidemic?

Under “original” logic – No!

Under “expanded” logic – No!
Looking for Everything Means It’s Harder to Find Any One Thing!

Under “restricted” logic – Yes!
It’s a Hard Problem Even When You Know What You’re Looking For!

Where’s Osama?!!!
Conclusions

• Improvements in biosurveillance are possible
• Incorporate CUSUM detection algorithms into EARS program
  – Validates earlier thesis work based on simulated data
• Continue using “restricted” logic

Further research opportunities:
★ Robustness across different diseases
★ Sensitivity analysis of thresholds and baseline periods
Impact

- Monterey County Health Department
- Western Regional Epidemiology Network (WREN) Conference
- American Public Health Association
“LT Hagen’s research has helped the Monterey County Health Department (MCHD) gain a deeper understanding of how we can and should use EARS to assess incoming data for potential outbreaks. Not only has her work validated some of our current practices, but it demonstrates that significant improvements in biosurveillance — both locally and nationally — are possible.

Furthermore, the collaborative effort between MCHD and NPS, of which LT Hagen has been an integral part, is a unique and groundbreaking partnership that is necessary for improving U.S. homeland security. LT Hagen’s research contributes to better public health preparedness that will help ensure the health and safety of the United States.”

- Dr. Krista Hanni

Monterey County Preparedness Manager
Questions?