Infrastructure and Methods to Support Real Time Biosurveillance

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Category A agents

- Anthrax (*Bacillus anthracis*)
- Botulism (*Clostridium botulinum* toxin)
- Plague (*Yersinia pestis*)
- Smallpox (*Variola major*)
- Tularemia (*Francisella tularensis*)
- Viral hemorrhagic fevers
  - *filoviruses* [e.g., Ebola, Marburg] and
  - *arenaviruses* [e.g., Lassa]
Natural history—Anthrax

- Incubation is 1-6 days
- Flu like symptoms followed in 2 days by acute phase, including breathing difficulty, shock.
- Death within 24 hours of acute phase
- **Treatment must be initiated within 24 hours of symptoms**
Attack scenario—Anthrax

- State sponsored terrorist attack
- Release of Anthrax, NYC subway
- No notification by perpetrators
- **1% of the passengers exposed during rush hour will contract the disease**
Need for early detection

The diagram illustrates the importance of early detection in disease management. It shows two phases:

- **Phase I**: Initial Symptoms
- **Phase II**: Acute Illness

The early detection curve (blue line) shows a significant gain of 2 days compared to traditional disease detection (light blue line). This gain is achieved within the incubation period, indicating the effectiveness of early detection in the treatment and management of illnesses.
Until now, there has been no real time surveillance for *any* diseases.

The threat of bioterrorism has focused interest on and brought funding to this problem.
Where can real time information have a beneficial effect?

- **Diagnosis**
  - Decision Support

- **Response**
  - Coordination
  - Communication

- **Surveillance**
  - Detection
  - Monitoring
Surveillance of what?

- Environment
  - Biological sensors
- Citizenry
  - Health related behaviors
  - Biological markers
- Patient populations
  - Patterns of health services use
  - Biological markers
Syndromic surveillance

- Use patterns of behavior or health care use, for early warning
- Example, *influenza-like illness*
- Really should be called “prodromic surveillance”
Early implementations

- **Drop in surveillance**
  - Paper based
  - Computer based

- **Automated surveillance**
  - Health care data
  - “Non-traditional” data sources
**TABLE.** Definitions and frequency of syndromes under surveillance — New York City, 2001

<table>
<thead>
<tr>
<th>Syndrome</th>
<th>Description</th>
<th>Potential BT agent/exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety</td>
<td>Anxiety reaction including somatic complaints, insomnia</td>
<td>None</td>
</tr>
<tr>
<td>Asthma</td>
<td>Exacerbation of underlying respiratory condition</td>
<td>None</td>
</tr>
<tr>
<td>Botulism-like</td>
<td>Cranial nerve impairment with weakness</td>
<td>Botulinum toxin</td>
</tr>
<tr>
<td>Death</td>
<td>Unexplained death with history of fever</td>
<td>Many</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>Diarrhea/gastroenteritis (including vomiting or abdominal cramps)</td>
<td>Food/water</td>
</tr>
<tr>
<td>Inhalational</td>
<td>Smoke or dust inhalation</td>
<td>None</td>
</tr>
<tr>
<td>Neurologic</td>
<td>Meningitis, encephalitis, or unexplained acute encephalopathy</td>
<td>Venezuelan Equine Encephalitis</td>
</tr>
<tr>
<td>Rash</td>
<td>Rash with fever (both must be present)</td>
<td>Smallpox</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Upper- or lower-respiratory infection with fever</td>
<td>Anthrax, plague, tularemia</td>
</tr>
<tr>
<td>Sepsis</td>
<td>Sepsis or nontraumatic shock</td>
<td>Many</td>
</tr>
<tr>
<td>Trauma</td>
<td>Trauma</td>
<td>None</td>
</tr>
<tr>
<td>None of the above</td>
<td>Not in any of the above categories</td>
<td>None</td>
</tr>
<tr>
<td>Missing</td>
<td>Form left blank</td>
<td>—</td>
</tr>
</tbody>
</table>
Health care data sources

- Patient demographic information
- Emergency department chief complaints
- International Classification of Disease (ICD)
- Text-based notes
- Laboratory data
- Radiological reports
- Physician reports (not automated)
- ?new processes for data collection?
“Non traditional data sources”

- Pharmacy data
- 911 operators
- Call triage centers
- School absenteeism
- Animal surveillance
- Agricultural data
Data Integration

- Technical challenges
- Security issues
- Political barriers
- Privacy concerns
Data Issues

- Data often collected for other purposes
- Data formats are nonstandard
- Data may not be available in a timely fashion
- Syndrome definitions may be problematic
Data quality

- Data often collected for other purposes
  - What do the data represent?
  - Who is entering them?
  - When are they entered?
  - How are they entered? Electronic vs. paper
## Measured quality/value of data

<table>
<thead>
<tr>
<th></th>
<th>CC: all resp</th>
<th>ICD: upper resp</th>
<th>ICD: lower resp</th>
<th>CC or ICD: all resp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>sens [95% CI]</strong></td>
<td>.49 [.40-.58]</td>
<td>.67 [.57-.76]</td>
<td>.96 [.80-.99]</td>
<td>.76 [.68-.83]</td>
</tr>
<tr>
<td><strong>spec [95% CI]</strong></td>
<td>.98 [.95-.99]</td>
<td>.99 [.97-.99]</td>
<td>.99 [.98-.99]</td>
<td>.98 [.95-.99]</td>
</tr>
</tbody>
</table>
Syndrome definition

- May be imprecise
- Sensitivity/Specificity tradeoff
- Expert guided vs. machine-guided?
Modeling the Data

- Establishing baseline
- Developing forecasting methods
- Detecting temporal signal
- Detecting spatial signal
Are data available to establish baseline?

- Periodic variations
  - Day
  - Month
  - Season
  - Year
  - Special days

- Variations in patient locations
  - Secular trends in population
  - Shifting referral patterns
  - Seasonal effects
Boston data

- Syndromic surveillance
- Influenza like illness
- Time and space
Total ED Volume 1992-2001

Forecasting
Components of ED volume

Seasonal components of ED Volume

RESP
GI
PAIN
INJURY
SKIN
OTHER
ED Resp Volume, 1992-2001
Principal Fourier component analysis

Power spectrum of Total ED volume 1992-2001

- 1 year
- 1/3 year
- 1 week
- .5 week
ARIMA modeling
Forecasting performance

• Overall ED Volume
  – Average Visits: 137
  – ARMA(1,2) Model
  – Average Error: 7.8%
Forecasting

ED Resp Volume: Actual vs. Forecast
Forecasting performance

• Respiratory ED Volume
  – Average Visits: 17
  – ARMA(1,1) Model
  – Average Error: 20.5%
all ED visits, 1999
Seasonal distributions

Distribution of interpoint distances between emergency dept. patients
A curve fit to the cumulative distribution

Distribution of interpoint distances between emergency dept. patients
combine seasons, 1999

Beta Curve:  \( \text{Thresh}=-0.02 \text{ A}=1.45 \text{ B}=5.58 \text{ Scale}=95.5 \)
A simulated outbreak
The cluster

Curve: Beta (Theta=-0.02 Scale=95.5 a=1.44 b=5.57)
## EMERGENCY DEPARTMENT SCOPE

### Actual Versus Forecasted Visits

<table>
<thead>
<tr>
<th>Syndrome</th>
<th>Actual</th>
<th>Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dermatological</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Gastro-Intestinal</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>General Surgical</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Genito-Urinary</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Infection</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Injury</td>
<td>41</td>
<td>33</td>
</tr>
<tr>
<td>Internal Medicine</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Meningitis</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Neurological</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Pain</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Respiratory</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>Psychological</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>General Sickness</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Other</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Total Visits</td>
<td>139</td>
<td>120</td>
</tr>
</tbody>
</table>

Sampled on Thu, Sep 19 2012 at 2:45 PM
Major issues

- Will this work at all???
- Can we get better data?
- How do we tune for a particular attack?
- What to do without training data?
- What do we do with all the information?
- How do we set alarm thresholds?
- How do we protect patient privacy?
Will this work at all?

- A syndromic surveillance system operating in the metro DC area failed to pick up the 2001 anthrax mailings
- Is syndromic surveillance therefore a worthless technology?
- Need to consider the parameters of what will be detectable
- Do not ignore the monitoring role
Getting better data

- Approaches to standardizing data collection
  - DEEDS
  - Frontlines of Medicine project
  - National Disease Epidemiologic Surveillance System, NEDSS
Tuning for a particular attack

- Attacks may have different “shapes” in the data
- Different methods may be more well suited to detect each particular shape
- If we use multiple methods at once, how do we deal with multiple testing?
A syndromic surveillance system operating in the metro DC area failed to pick up the 2001 anthrax mailings.

Is syndromic surveillance therefore a worthless technology?

Need to consider the parameters of what will be detectable.

Do not ignore the monitoring role.
Getting better data

- Approaches to standardizing data collection
  - DEEDS
  - Frontlines of Medicine project
  - National Disease Epidemiologic Surveillance System, NEDSS
No training data

- Need to rely on simulation
- Imprint an attack onto our data set, taking into account regional peculiarities
  - Artificial signal on probabilistic noise
  - Artificial signal on real noise
  - Real signal (from different data) on real noise
What do we do with all of this information?

- Signals from same data using multiple methods?
- Signals from overlapping geographical regions?
- Signals from remote geographical regions?

✓ Note: This highlights the important issue of interoperability and standards
Protecting patient privacy

- HIPAA and public health
- Mandatory reporting vs. syndromic surveillance
- The science of anonymization
- Minimum necessary data exchange
- Special issues with geocoded data
Table 1. Detection performance of filters given simulated outbreaks 7-days long and 20 visits per day, with 95% confidence intervals shown.

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Day</td>
<td>0.30 [0.28,0.32]</td>
<td>0.97 [0.96,0.98]</td>
</tr>
<tr>
<td>Moving Avg</td>
<td>0.65 [0.64,0.68]</td>
<td>0.97 [0.96,0.97]</td>
</tr>
<tr>
<td>Linear</td>
<td>0.71 [0.69,0.73]</td>
<td>0.97 [0.96, 0.97]</td>
</tr>
<tr>
<td>Exponential</td>
<td>0.61 [0.60,0.64]</td>
<td>0.97 [0.96, 0.98]</td>
</tr>
</tbody>
</table>