Planning for Public Health and Humanitarian Emergencies

MODELING APPROACHES TO INFORM GOOD DECISIONS

Margaret Brandeau
Stanford University
Key public health threats

- TERRORIST ATTACKS
- INFECTIOUS DISEASES
- NATURAL DISASTERS
- MANMADE DISASTERS
Relevant issues

- Uncertainty about timing and magnitude of events
- Preparedness is essential
  - Supply stockpiling
  - Response plans
- Preparedness budgets are limited
- How can model-based analyses help us make good preparedness plans?
1. Logistics of outbreak response

- Model of anthrax
- Evaluate the costs and benefits of various strategies for stockpiling and dispensing medical and pharmaceutical supplies
- Evaluate the benefits of improved surveillance
Anthrax Attack

Exposed Population

Dynamic compartmental model of anthrax disease progression

Model of dispensing

Local Dispensing Sites

Push Packs

Other SNS Inventories

Model of antibiotic supply chain

Local Inventories
Key inputs

Anthrax Attack

Exposed Population

Local Dispensing Sites

Dispensing capacity

Local inventories

Push packs

Other SNS inventories

Hospital capacity

Chance of attack

Attack size

Rate of awareness

Costs

Dispensing capacity

Local inventory levels

Availability of PPs, other SNS inventories
Model implementation

- Excel spreadsheet
- Difference equations
- Simulate 100 days, in 1-hour time increments
- Used data for a “typical city”
- Calculate costs, deaths, queue lengths, …
- Calculate cost/LY gained
## Anthrax Response Planning Model

<table>
<thead>
<tr>
<th>Initial Conditions</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population size</td>
<td>1000000</td>
</tr>
<tr>
<td>Local Inventory Stockpiles</td>
<td></td>
</tr>
<tr>
<td>Local stockpile - Days PEP</td>
<td>64525</td>
</tr>
<tr>
<td>Local stockpile - Days IV Abx.</td>
<td>781</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attack Scenario</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed</td>
<td>50,000</td>
</tr>
<tr>
<td>Not exposed but need prophylaxis</td>
<td>200,000</td>
</tr>
<tr>
<td>Not exposed, do not need prophylaxis</td>
<td>750,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Detection and response times</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time lag until attack detected</td>
<td>48</td>
</tr>
<tr>
<td>Time lag until local supply becomes available</td>
<td>5</td>
</tr>
<tr>
<td>Time lag until push packs become available</td>
<td>12</td>
</tr>
<tr>
<td>Time lag (after detection) until regional VMI becomes available</td>
<td>36</td>
</tr>
<tr>
<td>Time after arrival when Push Pack is ready for distribution</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Response Scenarios</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEP Regimen</td>
<td></td>
</tr>
<tr>
<td>Length (days) of a complete regimen</td>
<td>60</td>
</tr>
<tr>
<td>Length (days) distributed until SNS available</td>
<td>14</td>
</tr>
<tr>
<td>Push Pack Contents</td>
<td></td>
</tr>
<tr>
<td>Days PEP Cipro</td>
<td>216,000</td>
</tr>
<tr>
<td>Days PEP Doxy</td>
<td>2,502,000</td>
</tr>
<tr>
<td>Days IV Abx.</td>
<td>21,492</td>
</tr>
<tr>
<td>Vents</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rate of Becoming Aware or Seeking Treatment per Day</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>General population</td>
<td>33%</td>
</tr>
<tr>
<td>First stage/prodromal</td>
<td>33%</td>
</tr>
<tr>
<td>Second stage/fulminant</td>
<td>50%</td>
</tr>
<tr>
<td>Distribution Capacity</td>
<td>Value</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Number of Distribution Centres</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost and Capacity per Center</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity/hour</strong></td>
</tr>
<tr>
<td><strong>Cost/hour</strong></td>
</tr>
<tr>
<td>1,000/ hour, cost from Hupert model</td>
</tr>
<tr>
<td>User defined cost and Capacity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adherence</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEP Adherence rate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drug Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of doxycycline / 100 mg dose</td>
</tr>
<tr>
<td>Cost of ciprofloxacin / 100 mg dose</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Incremental Inventory and Distribution Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Inventory Purchases</td>
</tr>
<tr>
<td>Doxycycline (number of days)</td>
</tr>
<tr>
<td>Ciprofloxacin (number of days)</td>
</tr>
<tr>
<td>Additional Distribution Capacity</td>
</tr>
<tr>
<td>Number of Extra Centers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chance of Attack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Probability of Attack</td>
</tr>
</tbody>
</table>
Example output
Insights from analyses

- Limiting factor in anthrax response is local dispensing capacity
- Better to rely on regional and national inventories than on local inventories
- Improved surveillance can significantly reduce deaths IF dispensing capacity is adequate
Application to humanitarian logistics

Supply chain model combined with disease model

→ Can assess impact of different stockpiling and response strategies
2. Prepositioning of MCMs

- Model of anthrax

- Evaluate the costs and benefits of various strategies for prepositioning medical countermeasures (antibiotics)
  - Costs: initial and ongoing inventory costs
  - Benefits: chance of survival, assuming an event occurs (disease model)
Prepositioning strategies

Pre-Event

- Strategic National Stockpile
  - 12-Hour Push Packages
- State Stockpile
- Vendor Managed Inventory
- Local Inventories (Forward deployed)
- Distribution Center
  - (Usually state administered)
  - Receive/Stage/Store
- Local Receiving Center

Post-Event

- Points of Dispensing
  - Cached
  - Pre-dispensed
- End Users
  - Pre-Event
  - Post-Event
  - Forward deployed
  - Cached
  - Pre-dispensed
Cost-benefit tradeoffs

* Assuming an attack occurs
Insights from analyses

• Pre-dispensing is likely to be too expensive compared to its potential benefit in most locales

• One size does not fit all
  − Best strategy depends on attack risk, surveillance capability, current dispensing capacity, etc.

• Forward deployment and local caches may make sense in some locales
Application to humanitarian logistics

Inventory model combined with disease model

→ Can assess costs and benefits of alternative strategies for prepositioning medical supplies
3. Setting stockpile levels

- Evaluate the costs and benefits of various stockpile levels of needed response items

If pdf of demand is known, can use newsvendor analysis

If pdf of demand is unknown, can use planning scenarios

National Planning Scenarios
Defined by the National Preparedness Guidelines, these high consequence scenarios are being used to develop more granular strategic guidance and operational plans.

- Improvised Nuclear Device
- Improvised Explosive Device
- Major Earthquake
- Blister Agent
- Aerosol Anthrax
- Food Contamination
- Major Hurricane
- Toxic Industrial Chemicals
- Pandemic Influenza
- Foreign Animal Disease
- Radiological Dispersal Device
- Nerve Agent
- Plague
- Cyber Attack
- Chlorine Tank Explosion
- 

Homeland Security
Example: anthrax vaccine

- Assume an event scenario
  - Probability of an event requiring $n$ vaccine doses

- For different levels of doses held, calculate
  - Net present 10-year inventory cost
  - Expected lives saved over 10 years
  - Incremental cost per life saved, compared to next lower stockpiling level
Insights from analyses

- It may not make sense to stockpile tens of millions of doses of anthrax vaccine
- Stockpiling less anthrax vaccine would allow for expenditure on other inventory items
Application to humanitarian logistics

Inventory model combined with risk model

→ Can assess costs and benefits of alternative stockpiling levels
Concluding thoughts

- Preparedness problems are typically complex, with much uncertainty
- Model-based analyses can yield powerful, actionable insights
  - Can combine a logistics model with a model of population health and survival
- Simple analyses can be particularly useful
  - Easy and quick to develop, with modest data requirements

Thank you