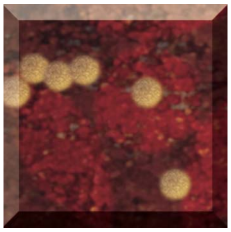

Simulated Release of Plague in Montgomery County, Maryland

Sheryl L. Happel Lewis, Protagoras N. Cutchis, Steven M. Babin, and Howard S. Burkom

Montgomery County, Maryland, a populous region in the metropolitan Washington, DC, area, is home to many military, government, and government contracting organizations and is therefore considered to be at increased risk for terrorist attacks, including those that involve the intentional release of pathogens. In September 2002, the county conducted an emergency preparedness and response exercise that simulated the release of the biological agent *Yersinia pestis*. APL assisted in the design of the exercise by determining the agent to be used, developing the release scenario, modeling the disease presentation in the population, and developing patient symptomatology. County health officials and hospital personnel used ESSENCE II, an electronic surveillance tool, to monitor health activity in the county and surrounding jurisdictions during the simulation.

INTRODUCTION

Five hospitals in Montgomery County, Maryland, conducted a joint exercise in September 2002 to fulfill testing requirements for the Joint Council for the Accreditation of Hospital Organizations. To maintain accreditation, each hospital must participate in a disaster drill that tests the organization's capacity to handle mass casualty scenarios. Because a biological attack is of great concern to all branches of the county government, the Emergency Management Services and Health and Human Services departments also participated in this exercise.

As the Montgomery County Health Department had an existing relationship with APL in the area of biosurveillance, the county's Exercise Design Team asked the Laboratory to help develop a realistic scenario for the exercise. For this simulated bioterrorist attack, APL was tasked with choosing the agent to be used, developing the attack scenario, modeling the disease in the population, and developing the symptomatology of the patients likely to present in each participating hospital.

Yersinia pestis (*Y. pestis*), in the form of pneumonic plague, was chosen as the release agent because of its lethality, short incubation period, and duration of resultant illness. These factors placed an immediate high demand on the medical and emergency resources of the hospitals and the county.

This article describes in detail the steps taken to develop a realistic scenario for the simulated release of *Y. pestis* in Montgomery County.

VARIABLES

The Agent

Pneumonic plague, caused by the bacteria *Y. pestis*, is a communicable disease with the potential to spread from person to person. It can be contracted through direct contact with aerosolized *Y. pestis* and spread by breathing in the bacteria suspended in respiratory droplets from an infected person (or animal). Exposure usually requires direct, close contact with the ill person or animal.[1] The incubation period for *Y. pestis* is between 2 and 4 days, and the duration of the illness is typically between 1 and 6 days. If left untreated, plague is fatal in about 90–95% of cases.[2]

Syndromic surveillance, the concept behind a biosurveillance system, requires that illnesses and the symptoms of those illnesses be aggregated into syndrome groups of interest. Patient count increases in these syndromic groupings might be the first indication (even before a diagnosis is made) that something is wrong in the overall health of the community. Pneumonic plague would result in increased patient counts in all eight syndromic groups monitored, including the following, with examples: Respiratory (cough, dyspnea, hemoptysis), Gastrointestinal (nausea, vomiting), Unspecified Infection (fever, flu-like symptoms), Death, Sepsis, Rash (petechiae, purpura, skin ulcers and sores), Neurological (severe headache, confusion, altered mental status, convulsions, meningitis), and Other (genitourinary, muscle strain from confusion with lymphadenopathy). However, the earliest syndromic increases would most likely be seen in the following categories, in decreasing order of occurrence: Unspecified Infection, Gastrointestinal, Respiratory, and Sepsis.[3]

Release

Many commuters, both in and around Washington, DC, rely on the Washington Metropolitan Area Transit Authority's Metro Rail System for transportation. Rail lines extend into several counties in both Virginia and Maryland, thus making the system accessible to a large number of people. The Red Line train services Montgomery County (Fig. 1). For purposes of this exercise, the Metro Rail System was the simulated method of transport for the individuals releasing the agent.

The simulation went as follows: On Monday morning, 23 September, six people boarded the trains between 6 and 8 a.m. (rush hour), with one person boarding at both Shady Grove and Glenmont each hour. These six people carried backpacks containing a slow-release container of the agent. Once onboard, they opened their backpacks to allow for aerosol release from the containers. At each station, the person exited the subway car and walked through as many additional cars as possible before the train resumed moving. Because the people moved through multiple cars, no one car received substantially greater amounts of the agent. This portion of the scenario merely served as background and was not actually played out.

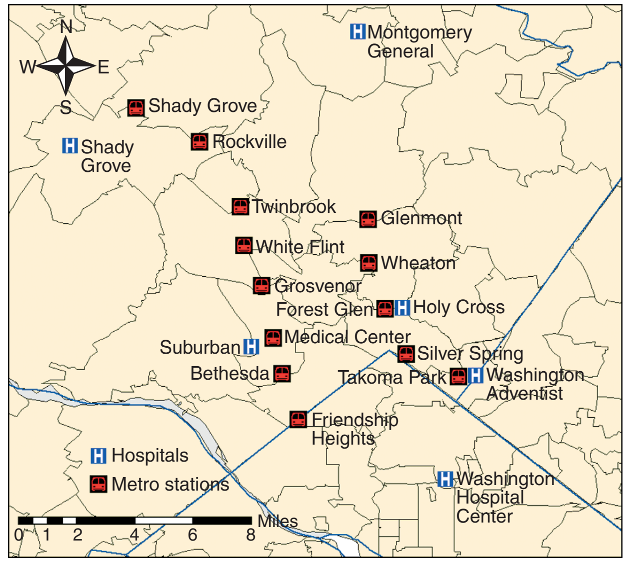

Figure 1. Distribution of Metro stations and hospitals in Montgomery County, Maryland.

The first simulated patients began appearing in various emergency departments throughout the county on Tuesday, 24 September. Hospitals used volunteers as well as pieces of paper on which symptoms were written to represent patients on the day of the simulation.

Demographics

Given the method of attack and the agent, the next step was to simulate the geographic distribution of the patient load to the five participating hospitals (Fig. 1). The total estimated Metro Rail Red Line ridership during the hours of attack was used to generate the total number of people exposed throughout the county. This number was calculated by averaging the morning rush hour ridership, i.e., the number of people entering the Red Line between 6 and 9 a.m. (morning peak in Table 1) from September 2000 and June 2001. This method was used because the June 2001 data may more accurately reflect current Metro ridership in that 9/11 may have affected the riders' commuting method. However, because Metro Rail ridership has risen in recent years, use of the most current data accounts for this increase. Then, using an estimated attack rate of 70% (number infected/number exposed), the number of infected was simulated. The attack rate of 70% was determined based on the simulated release method and the hypothesized communicability of the disease. Attack rates of diseases such as pertussis and chicken pox, which have a similar mode of transmission from person to person, were considered in approximating this attack rate, as was

Table 1. Estimated Metro ridership on 23 September 2002.

	Morning peak ridership	
Station	Total	Infected (70%)
Shady Grove	7200	5040
Rockville	2076	1453
Twinbrook	2064	1445
White Flint	1860	1302
Grosvenor	2284	1599
Medical Center	1107	775
Bethesda	2529	1770
Friendship Heights	2988	2091
Glenmont	3567	2497
Wheaton	2200	1540
Forest Glen	1359	951
Silver Spring	5535	3875
Takoma Park	2978	2085

the concentration of *Y. pestis* to which individuals were likely exposed.

The next step was to simulate the portion of the infected population that would go to each hospital. It would have been highly desirable to link this by zip code; however, the hospitals could not provide data on patients' zip codes and Metro Rail could not provide passengers' residency data. Therefore, at each station, the patients were apportioned to the nearest hospitals in an approximate ratio indicative of the relative distance to the hospitals. Table 2 shows the results of this apportionment. These ratios were then multiplied by the total number infected, for each station, that would present with symptoms to yield the total patient load for each hospital. Finally, lognormal onset rate curves were used to generate the number of patients arriving at each hospital during each time interval, as further discussed below.

Injects

To determine the injects, i.e., the number of individuals who would present with symptoms to each of the five hospitals during the exercise, a maximum likelihood epicurve was used. The mathematical basis for the epicurve was generated based on the work of Sartwell.[4]

The model calculates the maximum likelihood epicurve assuming a two-parameter lognormal distribution. Figure 2 shows incubation period histograms assuming that 26,421 people, the number calculated based on Metro Rail ridership, are infected. Here, 1 sigma is calculated assuming that cases within 1 standard deviation of the mean (in log space) fall within the typical 2- to 4-day incubation period; 2 sigma is for 2 standard deviations. The third curve is calculated assuming that 50% of the cases fall within the typical incubation period. Note, however, that some people may experience symptoms before 2 days or later than 4 days.

Once ridership was determined for each station, the numbers were multiplied by 70% to determine how many of those exposed were actually infected. The number infected (26,421) was then divided among the five hospitals as stated above. The number of infected and the incubation period of 2 to 4 days were both entered into the disease model to determine the lognormal distribution using the assumption that 50% of the infected people would fall into the 2- to 4-day incubation period. This distribution provided the percentage of infected people who would be symptomatic at each hour following the aerosol release. The percentage was then applied to the patient distribution of each hospital to calculate the number of individuals from each hospital that would

Table 2. Percentage of Metro riders apportioned to each Montgomery County hospital.

Station	Shady Grove	Montgomery General	Holy Cross	Suburban	Washington Adventist
Shady Grove	65	35	0	0	0
Rockville	55	45	0	0	0
Twinbrook	40	40	0	20	0
White Flint	40	10	10	40	0
Grosvenor	15	0	10	75	0
Medical Center	0	0	10	90	0
Bethesda	0	0	10	90	0
Friendship Heights	0	0	50	50	0
Glenmont	0	30	70	0	0
Wheaton	0	0	100	0	0
Forest Glen	0	0	100	0	0
Silver Spring	0	0	50	0	50
Takoma Park	0	0	0	0	100

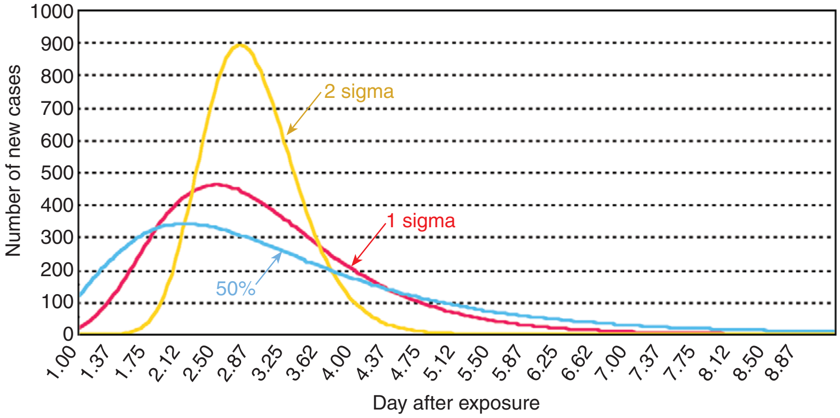

Figure 2. Epicurves used to generate inject numbers (total infected = 26,421, incubation period = 2–4 days).

be symptomatic. Because many people will self-medicate influenza-like illness, it was assumed that during the first day, 24 September, only 10% of symptomatic people would present to an emergency department, while 20% would present after midnight on the 25th.

The original inject numbers (Appendix A) provided to the hospitals were larger than needed for this exercise; therefore, the modified inject numbers (Appendix B) represent roughly 50% of the original figures. Although the modified inject numbers are a departure from the actual numbers of patients expected to be seen during an outbreak of pneumonic plague in this release scenario, the original numbers were used by the county's Health Department and hospitals for resource planning.

THE SIMULATION

The simulation took place over the course of 1 day using an accelerated timeline. As noted earlier, the agent was released on Monday, 23 September, with the first patients presenting to the emergency department between 6 p.m. and midnight on 24 September.

To monitor health activity throughout the simulation the ESSENCE II (Electronic Surveillance System for the Early Notification of Community-based Epidemics, version 2) surveillance tool was used. ESSENCE II tracks the occurrence of common diseases to enable the early recognition of abnormal disease patterns. (See the articles by Burkom and Lombardo for detailed discussions of ESSENCE II.)

During the simulation, the ESSENCE II Web site was updated with the inject data discussed above based on the simulation timeline. Members of the Montgomery County Biodefense Team, operating from a remote facility, reviewed the data as they were updated. The Biodefense Team's epidemiologist then communicated with emergency response personnel at the county's main Emergency Operations Center (EOC), the hospitals, and other county health officials.

ESSENCE II's ability to detect an attack was not tested in this exercise. However, based on the feedback received from end-users during the simulation, it was modified to provide optimal data visualization.

SUMMARY

This simulation exercise provided the feedback needed to further the development of the ESSENCE II Web site and insight into the kinds of information that would be most valuable in the event of a biological attack. County health departments, the ultimate end-users of ESSENCE II, need to be able to access and display data both quickly and concisely. This includes the ability to rapidly map the zip codes from which most people are presenting and to provide concise summary data for decision makers who must determine where to set up prophylaxis dispensing stations as well as triage centers for additional patients.

The county's public health officials (Fig. 3) learned that to effectively manage any type of biological attack, communications with the EOC would need vast improvement. One way that ESSENCE II can help is by providing quick summary views of patient activity at all of the hospitals in one geographic area rather than each hospital individually.

Although ESSENCE II's ability to detect a biological attack was not tested in this scenario, the tool proved to be valuable. The county epidemiologist and disease control practitioners had access to data, including specific patient symptomatology, and this enhanced their ability to effectively communicate with the hospitals, assist in resource management, and develop appropriate response plans.

Figure 3. Montgomery County public health officials review data that have come in from area hospitals.

APPENDIX A: ORIGINAL MONTGOMERY COUNTY INJECT SCHEDULE

			Hospital				
Inject number	Real time 25 Sep 2002	Event date in Sep 2002/time	Shady Grove	Montgomery General	Holy Cross	Suburban	Washington Adventist
1	7:00	24/0600–1200	23	17	33	23	17
2	7:10	24/1200–1600	19	14	27	19	14
3	7:20	24/1600–2000	23	16	32	22	16
4	7:30	24/2000–2200	12	8	18	12	10
5	7:40	24/2200–2300	6	5	9	6	5
6	7:50	24/2300–2400	6	5	9	6	5
		30 min for real-time testing					
7	8:20	25/2400–0130	13	9	19	13	10
8	8:30	25/0130–0220	13	10	19	13	10
9	8:40	25/0220–0330	14	10	19	13	10
10	8:50	25/0330–0430	14	10	20	13	10
11	9:00	25/0430–0530	14	10	20	14	10
12	9:10	25/0530–0630	14	10	20	14	10
13	9:20	25/0630–0700	14	10	20	14	10
14	9:25	25/0700–0800	14	10	20	14	10
15	9:30	25/0800–0900	14	10	20	14	10
		TOTAL	213	154	305	210	157

APPENDIX B: REVISED MONTGOMERY COUNTY INJECT SCHEDULE

			Hospital				
Inject number	Real time 25 Sep 2002	Event date in Sep 2002/time	Shady Grove	Montgomery General	Holy Cross	Suburban	Washington Adventist
1	7:00	24/0600–1200	12	9	17	12	9
2	7:10	24/1200–1600	10	7	14	10	7
3	7:20	24/1600–2000	12	8	16	11	8
4	7:30	24/2000–2200	6	4	9	6	5
5	7:40	24/2200–2300	3	3	5	3	3
6	7:50	24/2300–2400	3	3	5	3	3
		30 min for real-time testing					
7	8:20	25/2400–0130	7	5	10	7	5
8	8:30	25/0130–0220	7	5	10	7	5
9	8:40	25/0220–0330	7	5	10	7	5
10	8:50	25/0330–0430	7	5	10	7	5
11	9:00	25/0430–0530	7	5	10	7	5
12	9:10	25/0530–0630	7	5	10	7	5
13	9:20	25/0630–0700	7	5	10	7	5
14	9:25	25/0700–0800	7	5	10	7	5
15	9:30	25/0800–0900	7	5	10	7	5
		TOTAL	109	79	156	108	80

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