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An ounce of prevention is worth a pound of cure: Improving communication to reduce mortality during bioterrorism responses

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Abstract

Objective: *To identify communication needs and evaluate the effectiveness of alternative communication strategies for bioterrorism responses.*

Methods: *We provide a framework for evaluating communication needs during a bioterrorism response. Then, using a simulation model of a hypothetical response to anthrax bioterrorism in a large metropolitan area, we evaluate the costs and benefits of alternative strategies for communication during a response.*

Results: *Expected mortality increases significantly with increases in the time for attack detection and announcement; decreases in the rate at which exposed individuals seek and receive prophylaxis; increases in the number of unexposed people seeking prophylaxis; and increases in workload imbalances at dispensing centers. Thus, the timeliness, accuracy, and precision of communications about the mechanisms of exposure and instructions for obtaining prophylaxis and treatment are critical. Investment in strategies that improve adherence to prophylaxis is likely to be highly cost effective, even if the improvement in adherence is modest, and even if such strategies reduce the prophylaxis dispensing rate.*

Conclusions: *Communication during the response to a bioterror attack must involve the right information delivered at the appropriate time in an effective manner from trusted sources. Because the response system for bioterror communication is only fully operationalized once an attack has occurred, tabletop planning and simulation exercises, and other up-front investments in the design of an effective communication strategy, are critical for effective response planning.*

Key words: anthrax, risk communication, bioterrorism, preparedness planning

Introduction

An essential component of an effective bioterrorism response is timely and effective communication among public health officials, first responders, and the public. In this article, we provide a framework for evaluating communication needs during a bioterrorism response. Then, using a simulation model of a hypothetical response to anthrax bioterrorism in a large metropolitan area, we evaluate the costs and benefits of alternative strategies for communication during a response.

The chronological steps in a bioterrorism response, and the accompanying information needs, are illustrated in Figure 1. After an attack occurs and has been detected, the agent of the attack and relevant information about the agent must be communicated to public health officials, first responders, and the public. For example, is the agent communicable, what are the symptoms associated with infection, and how is exposure to the agent treated? Members of the public need to know what to do if they were exposed, and what to do if they were not exposed. Then, prophylaxis and treatment centers must be mobilized. Public health and medical personnel need to know which dispensing centers to open, and who should report to staff them. Staff at the prophylaxis dispensing centers needs to be familiar

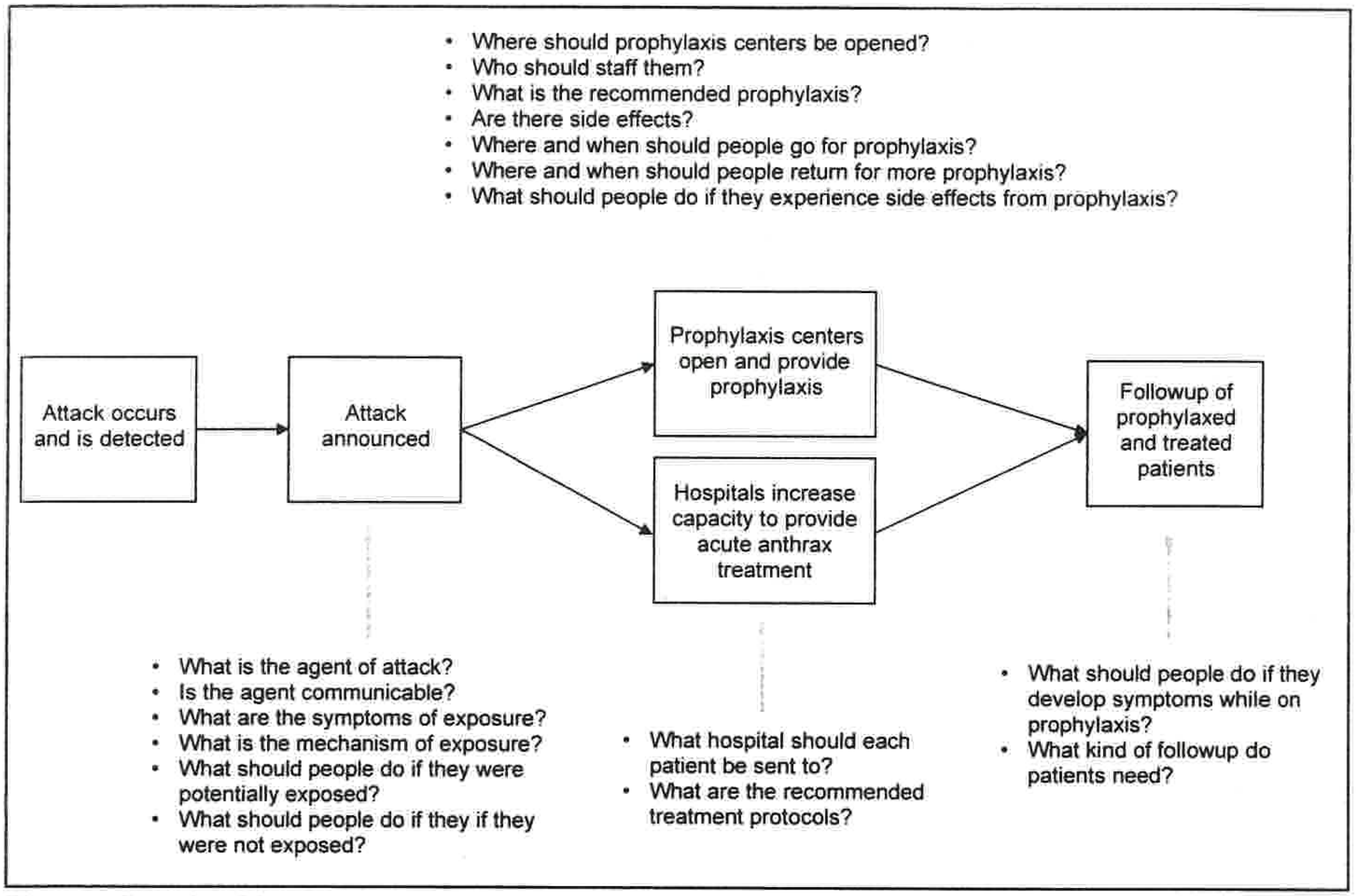

Figure 1. Steps in a bioterror response and associated information needs.

with recommended prophylaxis regimens and potential side effects of the dispensed medications. Members of the public need to understand where they should go to receive prophylaxis and what to expect from their course of antibiotics or vaccination. Further, they need to understand what their expected follow-up regimen should be, symptoms of disease progression, and side effects from medications. Symptomatic individuals will have to be admitted to hospitals or other treatment centers. Which hospitals have available capacity? What treatments should those hospitals provide?

In the following sections, we review communication lessons learned in related disaster responses. We then present a framework for evaluating communication needs during a response to bioterrorism. Using a simulation model of a bioterrorism attack involving aerosolized anthrax, we evaluate the costs and benefits of alternative strategies for communication during a response. We evaluate how an effective communication failure can impede an effective response, and we evaluate the cost effectiveness of various strategies for improving communication. We conclude with a discussion of our key findings.

Communication lessons learned from past disasters

Lack of public preparedness may hinder communications

A recent survey of preparedness among the general public for a public health crisis found that people were not as prepared as they thought they were, nor were they as informed about public health crises as they need to be.[1] Additionally, the public may be unable to act on advice due to a failure of advance preparedness. For example, an admonition to drink only boiled water may be ignored if people do not have the means to boil water.

The public may not trust official disaster communications

Burton and Silver[2] found that the effectiveness of disaster evacuation warnings is directly related to the public's trust in government and the methods used to deliver the warnings. During the days just before Hurricane Katrina in August 2005, residents of New Orleans exhibited mixed reactions to the National Weather Service warnings about the impending hurricane. About 80 percent of the population believed the forecast that the hurricane would make landfall in New Orleans and fled to high ground before the storm arrived.[3] Governor Kathleen Blanco's deputy chief of staff began calling religious leaders to get out the word to evacuate because of their credibility with their parishioners. Council member Cedric Richmond began spreading the word of the impending storm and canvassed the entertainment district to urge people to leave.[3] Despite these efforts, "about 200,000 poverty-stricken people and others who refused to leave were left behind."[3]

Similarly, after the 1994 Northridge (Los Angeles) earthquake, city officials encouraged people to remain in their undamaged homes or go to American Red Cross shelters; however, thousands of people chose instead to live in the city's parks during a cold and rainy January. They mistrusted the information from the government, relying instead on their earlier life experiences in other countries, where buildings collapsed in earthquake aftershocks. When city officials needed to close the makeshift shelters in the parks, they had to assemble "reassurance teams" to speak with the head of each family, encouraging them to go home. These teams included a city building official and a religious leader of the appropriate sect to provide credibility.[4]

The public may overreact or underreact to disaster communications

As the above examples show, the public may underestimate their risk in a disaster. Additionally, the public may not respond to warnings if they are issued too frequently.[5]

At other times the public may overestimate their risk. For example, the 2001 anthrax attacks on the East Coast led to heightened vigilance by the general public, even thousands of miles away. People in California feared infection with anthrax from "white powder" and called local first responders for plaster dust, coffee creamer, and detergent found in their homes, as well as for truly suspicious envelopes. Despite the effort to reassure the public that an anthrax attack was unlikely to occur in Silicon Valley, more than 150 white powder calls were received by San Jose Fire Department in October 2001 alone.[6] This demand for service required the use of overtime personnel and the consumption of scarce financial resources to reassure the worried public.

Various agencies responsible for communication may not be coordinated

Many response agencies have prepared communication guides for responses to natural and manmade disasters. For example, the American Red Cross provides a guide that aims to provide common terminology for use in disaster communications,[7] a guide to successful disaster communications,[8] and online information about bioterrorism and communication in the event of a bioterrorist attack.[9] The Centers for Disease Control and Prevention's website, "Communicating in the First Hours: Initial Communication With the Public During a Potential Terrorism Event," provides a list of biothreat agents and information that would be needed by first responders and the public in the immediate aftermath of an attack.[10] Other federal, state, and local organizations have created similar communication guides with information for clinicians, first responders, and the public.[11-16] However, such efforts are largely independent and uncoordinated.

Factors affecting communication

After a bioterror attack has been detected, response officials must communicate among themselves, and then convey needed information to the public (Figure 2). Response officials comprise a diverse group of individuals and organizations, including government and public health officials, clinicians, and healthcare providers. These officials must plan and coordinate messages to be disseminated. Communication must then proceed from these response officials to diverse members of the public.

Figure 2. Factors influencing efficiency and effectiveness of communications during response to a bioterror attack.

Three groups of factors affect the efficiency and effectiveness of such communications. The first set of factors is relevant to the *response officials* providing information about the attack and about efforts to respond: Are they trusted agents? Are they credible, polite, and respectful? Do they engender a sense that an effective and appropriate response is being mounted? Have they been thoughtful about the content, format, and timing of information provided to the public?

The second set of factors relates to the *message* itself: How is the message delivered and what is the role of the media?[17] Does the affected population have access to the message (eg, if delivered on television, do people see the message)? Is the message differentiated for different recipient subgroups, while still being consistent with other messages?[18] Is the message accurate and precise, with face validity?[19] How can the risk be presented so that individuals perceive it accurately, as opposed to neglecting or overrating it?[19,20] Does the message require action on the part of the public or is it intended just to provide information?

The third set of factors include age (which is a marker for susceptibility, and also a predictor of behavior in response to information about risk), socioeconomic status (which is relevant to access to care, transportation, etc), and cultural factors such as language, race/ethnicity, and religion. What are their information needs, both in terms of the content and timing of the message? Individual risk factors (eg, age, mobility, susceptibility to the agent, proximity to the release) determine whether an individual needs to be informed as soon as possible after the detection of the attack (high risk), or if information provision can be postponed to avoid panic and congestion of the medical infrastructure (lower risk). Prioritization of messages can help tailor the communication effort to avert panic and put the existing response infrastructure to best use.

The alertness level of the population prior to a potential attack determines how individuals respond to the risk: if members of the public are already alert to the potential danger, the message can be conveyed calmly; if they are unaware, the message may need to be stronger to get people's attention.[20] The level of preparedness of the population prior to a potential attack is also relevant: if members of the public have prepared for such an eventuality by previous planning exercises or information, then they know where to turn to in search of information, first aid, resources, etc, when they are informed of an attack. Community involvement in the response also plays a key role: people may be calmer and react better when they are actively involved in crisis resolution than if they are asked to wait at home for events to unfold.[20]

Simulation model for anthrax bioterrorism

We developed a model to simulate the effects of a hypothetical aerosol release of *Bacillus anthracis* spores in a metropolitan area and those of alternative response strategies (Figure 3). We modeled the supply chain for medical and pharmaceutical supplies required for response to such an attack, and evaluated expected mortality in the population as a function of different communication strategies. The model is simulated on an hour-by-hour basis for 100 days (assuming that any illness and death resulting from the attack would occur within 100 days). Full details of the model and discussion of other uses of the model (eg, to

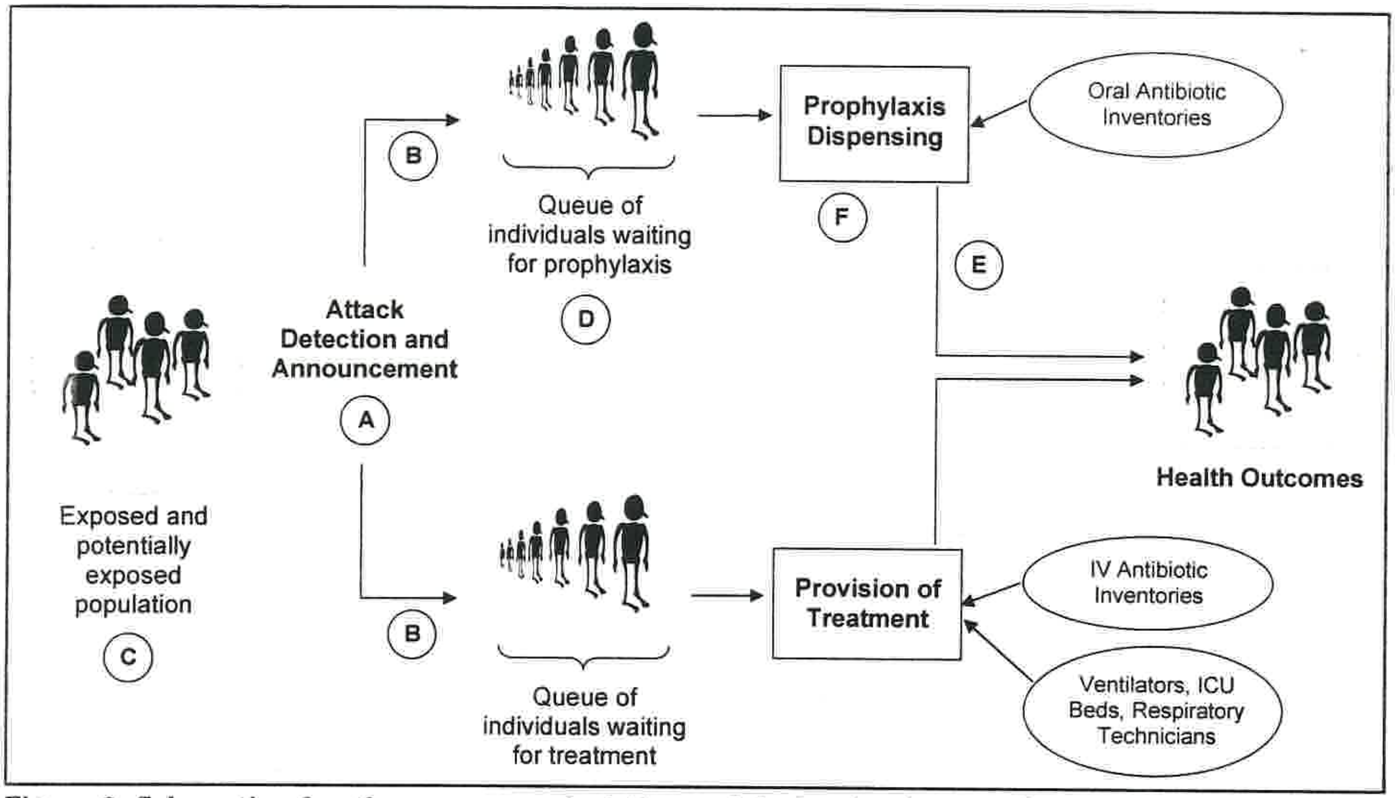

Figure 3. Schematic of anthrax response logistics model, showing impact of communication strategies considered (A-F).

evaluate strategies for stockpiling antiobiotics for prophylaxis and treatment, to evaluate the costs and benefits of variations in local dispensing rates) are provided elsewhere.[21,22]

The model includes a disease progression submodel that categorizes members of the population according to whether they were exposed to sufficent spores to become ill from anthrax, not exposed but believe they may have been exposed, or not exposed and believe they were not exposed. Exposed individuals can progress through three disease stages: asymptomatic infection, prodromal infection (characterized by nonspecific flu-like symptoms), and fulminant infection (severe symptomatic disease characterized by abrupt respiratory distress and shock that typically progresses rapidly to death). The disease progression model is based on a comprehensive review of the literature of 82 historical cases of inhalational anthrax, including 11 cases from the 2001 US anthrax attacks.[23]

We assumed that asymptomatic individuals became aware of the anthrax attack through alerts from the media, public health officials, and emergency response officials (Figure 3). Once asymptomatic individuals became aware of their potential exposure, we assumed they enter a first-come-first-served queue for prophylactic antibiotics (either ciprofloxacin or doxycycline). Once exposed individuals develop symptoms from anthrax infection (in the prodromal and fulminant stages), we assumed they enter a first-come-first-served queue for treatment, which consists of three antibiotics (ciprofloxacin or doxycycline with rifampin and clindamycin) administered intravenously in an intensive care setting with supportive care as necessary (eg, respiratory or cardiac support). We assumed that, without prophylaxis or treatment, anthrax infection would be 100 percent fatal and that, among fully adherent patients, prophylaxis would be 100 percent effective in preventing disease progression from the incubation to the prodromal stage.

In the model, the rate at which individuals receive prophylactic antibiotics depends on the dispensing rate, which in turn depends on the number of dispensing centers and their staffing levels, the rate per patient at which antibiotics are dispensed, and the availability of the needed antibiotics. Treatment is limited by the availability of intravenous antibiotics, intensive care unit beds, ventilators, and respiratory technicians. Antibiotics were assumed to come from three sources: local supplies, Push Packs sent from the Strategic National Stockpile, and vendor-managed inventories activated by the officials in charge of the Strategic National Stockpile.

Base values for model parameters are shown in Table 1. We assumed a metropolitan area of five million people, and a large-scale attack that exposes 250,000 people to anthrax. We assumed that an additional 1,187,500 people (25 percent of the unexposed population) would believe they were potentially exposed and would require prophylaxis (no reliable test for anthrax infection exists).

We assumed 20 dispensing centers, operating 14 hours per day, each of which could prophylax 1000 patients per hour. For treatment capacity of hospitals, we assumed 336 available intensive care unit (ICU) beds, 273 respirators, and 131 respiratory technicians.[21] Our assumptions about the available levels of local, regional, and national antibiotic inventories (for oral prophylaxis and intravenous treatment) are shown in Table 1. We assumed that the local level of inventory corresponded to enough inventory to prophylax or treat 1 percent of the population. Inventory levels for the Strategic National Stockpile were obtained from the Centers for Disease Control and Prevention.[30]

In the base case, the model estimated that 115,139 people would die from anthrax exposure.

Strategies for improving communication

We used the model to evaluate six types of strategies for improving communication that could decrease morbidity and mortality from an anthrax attack (Figure 3): strategies that change (A) the rate at which people become aware of an attack, (B) the rate at which people seek prophylaxis (and treatment if needed), (C) the fraction of unexposed people who present for prophylaxis, (D) the rates at which people present to appropriate dispensing centers, (E) the level of adherence to recommended prophylaxis, and (F) the prophylaxis dispensing rate.

Strategies that change the rate at which people become aware of an attack

Prophylaxis and treatment of exposed individuals cannot begin until the bioterrorism event has been recognized and information about the attack has been communicated to the public. We evaluated the effects on expected mortality of changing the time until event detection and announcement of that event. In the base case, we assumed that an attack would be detected and announced 48 hours after the release of anthrax spores. In sensitivity analyses, we varied the detection/announcement time from zero hours after the attack (as might happen during an attack announced by the bioterrorist) to 144 hours (6 days) after the attack (assuming that at 6 days, the relatively large number of patients presenting with symptoms would alert public health officials).

Figure 4 shows how expected mortality changes with this detection/announcement lag. In the base case, expected mortality is 115,139. If the attack detection and announcement instead takes 96 hours, then expected mortality is 134,516. On the other hand, if the attack is detected and announced in 24 hours, then 105,554 deaths occur. Figure 4 shows that expected deaths increase approximately linearly with the detection and announcement lag: each additional 12 hours of delay leads to approximately 4,600 more deaths.

Strategies that change the rate at which people seek treatment

A key factor in reducing expected morbidity and mortality after a bioterror attack is timely administration of prophylaxis and treatment to exposed individuals. For this to happen, individuals who have been exposed need to know about their potential exposure. They need to know where to go for treatment and what treatment to seek, and be willing to seek treatment. In the base case, we assumed that, each day after the attack has been announced, 33 percent of asymptomatic exposed (and potentially exposed) individuals, and 33 percent of individuals with prodromal

Table 1. Base values for model parameters		
Parameter	**Base Value**	**Source**
Demographic		
Population size	5,000,000	Assumed
Number exposed	250,000	Assumed
Number potentially exposed*	1,187,500	Assumed
Number not exposed	3,562,500	Assumed
Life years lost due to anthrax death†	43.4	Ref. 24
Attack detection, announcement, and awareness		
Time lag until attack detected and announced	48 h	Assumed
Attack awareness after announcement (per day)		
Potentially exposed individuals	33 percent	Assumed
Individuals with asymptomatic or prodromal infection	33 percent	Assumed
Individuals with fulminant infection	50 percent	Assumed
Disease progression		
Mean time in incubation stage‡	10.95 d	Ref. 23
Progression from prodromal to fulminant stage (per day)		
First three days	6.2 percent	Ref. 23
After first 3 days	43.3 percent	Ref. 23
Adherence with prophylaxis§	65 percent	Ref. 25
Adherence with treatment	100 percent	Assumed
Mortality rates (assuming adherence)		
No prophylaxis or treatment	100 percent	Ref. 23
Prophylaxis begun in incubation stage	100 percent	Ref. 23
Prophylaxis begun in prodromal stage	80 percent	Ref. 23
Treatment begun in prodromal stage	86 percent	Ref. 23
Treatment begun in fulminant stage	96.8 percent	Ref. 23
Dispensing capacity		
Number of dispensing centers	20	Assumed
Dispensing capacity/center/hour	1,000	Ref. 26

(continued)

Table 1. Base values for model parameters (continued)		
Parameter	**Base Value**	**Source**
Treatment capacity		
Available intensive care unit (ICU) beds	336	Ref. 21
Available ventilators	273	Ref. 21
Available respiratory technicians	131	Ref. 21
Antibiotic inventories		
Local inventories		
Doses of prophylaxis (patient days)	50,000	Assumed‖
Doses of IV antibiotics (patient days)	500	Assumed‖
Time lag after detection until supplies are available	5 h	Assumed
Push Pack inventories		
Doses of prophylaxis (patient days)	2,718,000	Ref. 27
Doses of IV antibiotics (patient days)	21,492,000	Ref. 27
Time lag after detection until supplies are available	12 h	Ref. 27
Vendor-managed inventories		
Doses of prophylaxis (patient days)	Unlimited	Assumed
Doses of IV antibiotics (patient days)	Unlimited	Assumed
Time lag after detection until supplies are available	36 h	Ref. 28
Costs		
Hourly cost per dispensing center	$4,178	Ref. 29

*These individuals were not exposed to enough spores to become ill, but need prophylaxis because they believe they may have potentially been exposed.

†We assumed that susceptibility to anthrax does not depend on age, and that the age distribution of the exposed population is the same as the age distribution of the population as a whole. Thus, an individual who dies from anthrax loses 43.4 future expected life years, which is the remaining average life expectancy in the population.

‡We modeled the fraction of individuals who progress from the incubation to prodromal stage per day[22] by a lognormal distribution with mean 10.95 days and dispersion factor $e^{(0.713)}$.

§We assumed that nonadherent individuals would receive only partial benefit from prophylaxis, depending on how long they took antibiotics. Details are provided elsewhere.[21,22]

‖Some communities hold no local antibiotic inventories, whereas others have significant stockpiles.[22] We assumed that the local community would have 50,000 doses of prophylactic antibiotics, which is the equivalent of 3571 14-day regimens (we assumed that abbreviated 14-day regimens would be given out prior to the arrival of the Push Packs from the Strategic National Stockpile.)

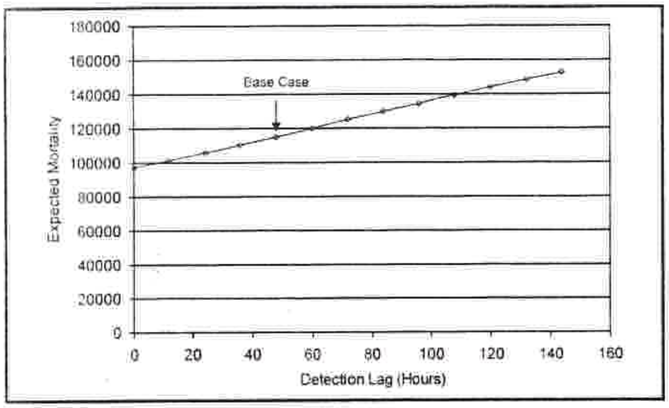

Figure 4. Expected mortality as a function of the number of hours until the attack is detected and announced to the public (the "detection lag").

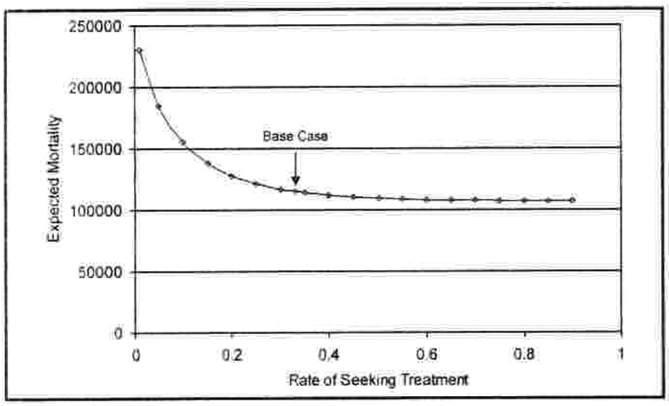

Figure 5. Expected mortality as a function of the fraction of exposed and potentially exposed people per day who seek treatment after the attack has been announced (the "average rate of seeking treatment").

infection, would seek prophylaxis. This daily fraction depends on the content of the message, and the communication media used by public officials. In sensitivity analysis, we varied this fraction from 1 percent to 90 percent.

Figure 5 shows how the rate of seeking treatment affects expected mortality. The actual rate of seeking treatment could be higher than the base case if the message is particularly effective in reaching affected individuals and convincing them to seek treatment. For example, if 50 percent of affected but untreated individuals seek treatment each day, then 109,607 deaths occur. Alternatively, the rate of seeking treatment could be lower than our assumption in the base case if the public does not understand or does not trust the message or its sender. For example, if only 10 percent of affected people seek treatment per day after the attack is announced, then 155,236 deaths occur. Figure 5 shows that, as the rate of seeking treatment decreases, deaths increase exponentially. Thus, it is critical that messages about the attack reach affected individuals quickly, and convince them to seek appropriate prophylaxis and treatment.

Strategies that affect the fraction of unexposed people who present for prophylaxis

In large urban areas, it is essential that individuals understand their risk of having been exposed. Such understanding depends critically on information from public health officials regarding the nature of the attack. If this information is not clearly communicated, large numbers of unexposed individuals could present for prophylaxis, thereby delaying the administration of drugs to those who have actually been exposed.

Exposure to an aerosol release of anthrax spores depends on several factors including the number of spores released, the wind speed and direction, and population density. Because no reliable test for anthrax exposure exists, individuals who suspect that they have been exposed must receive prophylaxis. In a diffuse attack (eg, 2001 anthrax exposure in a postal facility or in the Federal Office Building),[31] because of the lack of a reliable test for anthrax exposure, many potentially unexposed individuals who were in a high-risk environment may require prophylaxis. Additionally, other unexposed individuals with very little chance of exposure may also seek prophylaxis in the (false) belief that they were exposed. The size of this population could be considerable if key information about the biothreat agent, its natural history, and methods of exposure have not been effectively communicated.

In the base case, we assumed that 25 percent of the unexposed population (1,187,500 people) would seek prophylaxis due to potential exposure. Better information about exposure risk factors could change this number—as could worse (or no) information. Thus, we varied the number of individuals seeking prophylactic antibiotics from 100,000 to five million (ie, 2 percent to 95 percent of the unexposed population).

Figure 6 shows that expected mortality increases as the number of unexposed people who seek prophylaxis

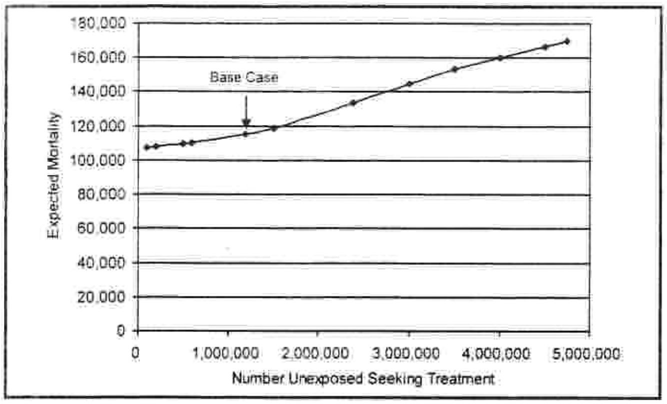

Figure 6. Expected mortality as a function of the number of unexposed people who seek treatment.

increases: these unexposed individuals increase congestion at dispensing centers and diminish inventories of prophylactic antibiotics. If half as many unexposed people seek prophylaxis as in the base case, then deaths decrease from 115,139 to 109,908; and if only 100,000 unexposed people seek prophylaxis, then deaths decrease further to 107,431. Alternatively, an unclear message or one that caused panic could cause more unexposed people to seek prophylaxis than we assumed in the base case.[Alternatively, an unclear message or one causing panic could lead to more unexposed people than in the base case to seek prophylaxis.] If, for example, twice as many unexposed people seek prophylaxis, deaths increase to 133,248. Figure 6 shows that the number of unexposed people who seek prophylaxis can have a significant impact on expected mortality. This analysis underscores the need for announcements by public officials about the attack to be informative and precise about the mechanisms of exposure.

Strategies that affect the rates at which people present to appropriate dispensing centers

In a large urban area, a number of different dispensing centers will be set up. It is important that exposed individuals know which center they should go to, and when. Without this information, significant imbalances in workload across the dispensing centers can occur, thus delaying administration of prophylaxis and treatment. In the base case, we assumed that people seeking prophylaxis would report in equal numbers to the 20 dispensing centers (ie, each would serve 5 percent of people seeking prophylaxis). In this idealized situation, a plan has been made regarding assignment of individuals to dispensing centers, this plan has been communicated to the public, and individuals have followed the plan. In an actual response, if individuals do not understand where they should report for prophylaxis dispensing, or if they are unwilling or unable to report to that center, different dispensing centers may experience quite different workloads. In sensitivity analysis, we varied the workload distribution by assuming that two of the 20 distribution centers would have a higher than average workload (ranging from 5 percent to 25 percent of the workload at each of the two centers), with the remaining workload distributed equally among the other 18 distribution centers.

Figure 7 shows that expected mortality is likely to increase significantly if patients present to already overloaded dispensing centers. For example, if two dispensing centers each have triple the average workload (ie, each processes 15 percent of total patients), then expected mortality increases by about 10 percent from the baseline estimate of 115,139 to 126,307. Greater workload imbalances lead to even higher expected mortality. Clear communication to the public about where they should go for prophylaxis may help equalize dispensing center workloads and minimize expected mortality.

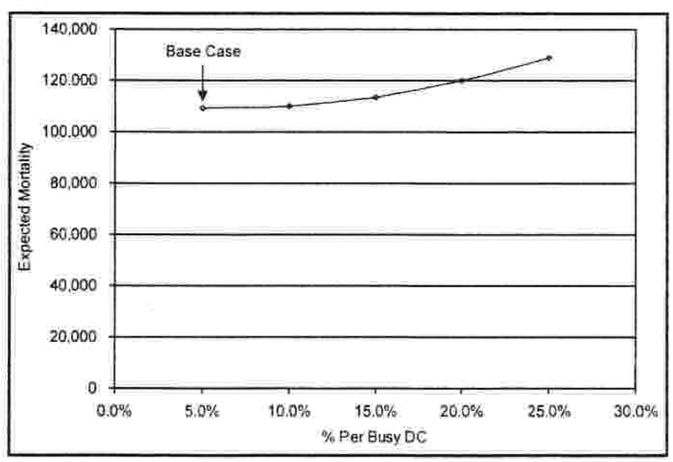

Figure 7. Expected mortality as a function of dispensing center workload imbalance. The x-axis shows the workload of the two busiest dispensing centers; the remaining patient workload is assumed to be equally distributed among the 18 other dispensing centers.

Strategies that affect adherence to prophylaxis protocols

Once individuals have received prophylaxis, their survival depends on adherence to prophylaxis. Effective communication is required to educate patients regarding the rationale for remaining on prophylaxis regimens despite being asymptomatic—a challenge that has been well demonstrated historically for a variety of medical conditions (eg, patients with hypertension are less likely to adhere to medication regimens than those with symptomatic conditions[32]).

Based on the United States experience after the 2001 anthrax attacks, the base case assumed a 65 percent rate of adherence to prophylactic antibiotic regimens.[25] In sensitivity analysis, we varied the level of adherence with prophylaxis up to 90 percent. We also considered potential costs associated with improving adherence; such costs might reflect the cost of counseling or other efforts to improve adherence.[33] Adherence could be improved by strategies such as counseling sessions, showing a video about adherence to the public while they are in the prophylaxis queue, translators, or educational brochures provided as part of the prophylaxis dispensing process.

Figure 8 shows the cost effectiveness of interventions that improve adherence from the baseline level of 65 percent to a higher level, for four different levels of intervention cost. For an inexpensive adherence intervention costing $10 per person, even if the improvement in adherence is slight (eg, an increase only to 67 percent), the intervention will be cost effective (eg, incremental cost of $12,519 per life year gained). If this inexpensive intervention can improve adherence to 90 percent, then it costs only $3,050 per life year gained. Even at a cost of $100 per person, an intervention that raises adherence modestly from 65 percent to 70 percent would have a cost-effectiveness ratio of $42,700 per life year gained. Thus, investment in strategies that can improve adherence with prophylaxis is likely to be highly cost effective.

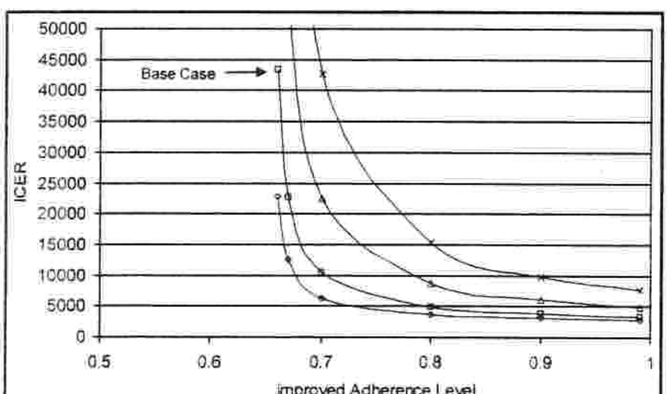

Figure 8. Cost per life year gained of a counseling session that improves adherence to prophylaxis from 65 percent to 95 percent, as a function of the per person counseling cost.

Strategies that affect local dispensing capacity

Dispensing capacity is strongly influenced by efficiency of dispensing operations. A key aspect of efficient dispensing is the ability to effectively communicate needed information to each patient in a timely fashion. This could, for example, reflect the availability of translators for non-English speaking populations, and/or the availability of other written material (either pamphlets or web-based) that describe the medications, vaccines, side effects, and symptoms associated with the agent and the prophylaxis provided. Conversely, strategies that improve adherence—for example, the use of translators who can explain prophylaxis regimens to patients, or additional counseling given when prophylaxis is dispensed—may increase the time spent dispensing prophylaxis to individual patients, and thus decrease the effective local dispensing capacity.

In the base case, we assumed that each dispensing center could dispense prophylactic antibiotics to 1000 people per hour (for 14 hours per day; thus, $20 \times 14{,}000 = 280{,}000$ people could receive prophylaxis per day). In sensitivity analysis, we varied the dispensing capacity at each center from 250 to 3,000 people per hour.

Figure 9 shows that as dispensing capacity decreases, expected mortality increases exponentially. In the base case, with dispensing capacity of 1,000 patients per hour at each dispensing center, expected mortality is 115,139. If dispensing capacity is only 500 people per hour, then expected mortality is 137,705; and if dispensing capacity is 250 people per hour, then expected mortality is 175,839.

Figure 10 shows "iso-mortality" lines corresponding to the base case expected mortality (115,139

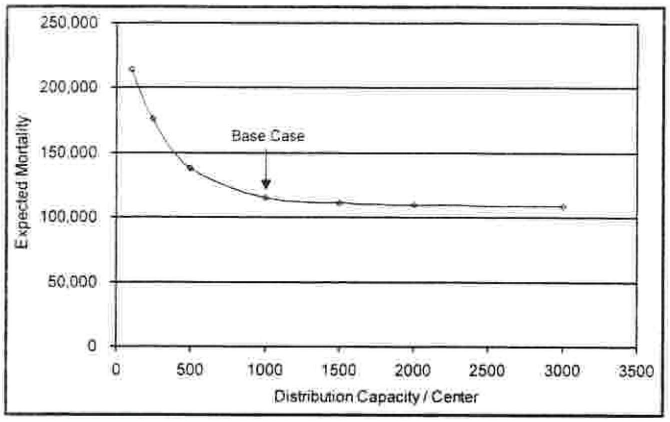

Figure 9. Expected mortality as a function of local dispensing center capacity (number of patients per hour).

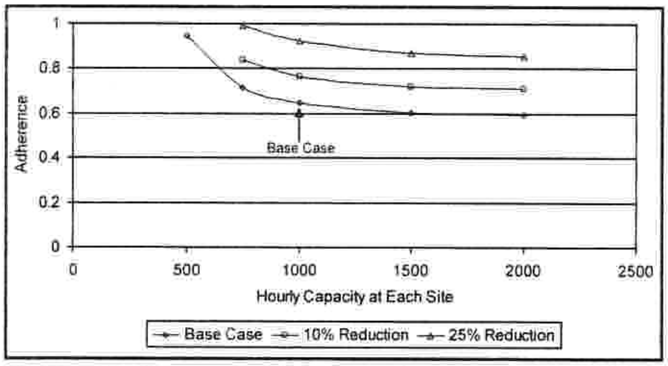

Figure 10. Isomortality curves (base case mortality, and 10 percent and 25 percent less mortality than the base case) as a function of local dispensing capacity and level of adherence to prophylaxis.

deaths), a 10 percent reduction in mortality (103,625 deaths), and a 25 percent reduction in mortality (86,354 deaths). Each line shows the combinations of local dispensing capacity and patient adherence with prophylaxis that result in the specified level of expected mortality. For example, if more comprehensive communication with patients diminishes effective dispensing capacity by 25 percent (from 1,000 patients per hour at each site to 750), then to maintain the same expected mortality as in the base case, adherence must improve from the baseline level of 65 percent to 71.5 percent. To achieve 10 percent less expected mortality than in the base case, again with capacity diminished by 25 percent, adherence would have to increase to 84 percent. Thus, communication strategies that improve adherence but reduce the dispensing rate can be beneficial if they improve adherence enough.

Discussion

Effective communication will play a key role in the success of any bioterror response. The quality of this communication depends on three sets of factors: those related to the response *officials* providing the message, those related to the *message* itself, and those related to the *population* for whom the message is intended.

Our analysis of strategies that affect communications yielded four main results. First, we found that following an outbreak of inhalational anthrax resulting from a bioterrorist attack, mortality is critically dependent on the rate at which affected individuals learn of the attack and seek treatment. Thus, in addition to planning for rapid dissemination of information in the event of an attack, public health officials should consider up-front investments in the design of effective strategies for communicating with the public. This may include, for example, training of community leaders and other trusted agents, the development in advance of communication procedures for all involved authorities, and careful consideration in advance of the appropriate types of messages and media channels.

Second, we found that the number of unexposed people who seek prophylaxis has a significant effect on expected mortality. This underscores the importance of effective communication about the exposure and infectivity of the biothreat agents.

Third, we found that investment in strategies that improve adherence to prophylaxis is likely to be highly cost effective, even if the improvement in adherence is modest, and even if such strategies reduce the prophylaxis dispensing rate. Additionally, because mortality is highly dependent on the local prophylaxis dispensing capacity, communication strategies that can help speed up the dispensing process (eg, translators) can reduce expected mortality.

Fourth, workload imbalances at the dispensing centers can increase expected mortality. Thus, it is essential that the public receive clear communication about where and when to report for prophylaxis dispensing.

Just as redundancy in other aspects of disaster responses is critical for ensuring response capacity (such as multiple potential triage sites for earthquake response in the event that some are damaged), redundancy and reinforcement of the information communicated during a bioterrorism response is similarly important. For example, a strategy of "double information targeting" might simultaneously plan for communication on a general level to the affected region (eg, via mass media in that region, or nationwide) and on a second level to the affected community (eg, via local news and word-of-mouth campaigns in a particular neighborhood). Additionally, a "sequential specification of information" strategy could first provide information of a general nature that typically does not require action on the part of the public, with subsequent information becoming more specific and requiring increasing levels of action by the public (eg, information about where the sickest individuals should present for treatment and where critically exposed individuals should present for prophylaxis, while low-risk individuals await further instructions). In all cases, messages must be consistent.

Although considerable research exists on emergency risk communication, such research provides little insight into how the public will respond to a bioterror attack. Most studies of risk communications have involved natural disasters.[34] Because the public has little experience with biothreat agents, public education and awareness campaigns that provide information about various biothreat organisms and ongoing preparedness plans can help ensure a more efficient and effective response. Similar campaigns have been mounted for other public risks such as pandemic influenza.[35]

The response system for bioterror communication is only fully operationalized once an attack has occurred. Thus, tabletop planning and simulation exercises are critical for effective response planning. Such exercises can help to ensure that public health and other key response decision makers receive and provide appropriate information in the best sequence. As we have highlighted, effective bioterror response communication must involve the right information, delivered at the appropriate time, in an effective manner, and from trusted sources. Indeed, we suspect that effective response communication for other disasters that require similar types of action on the part of responders and the public (such as presenting to dispensing centers for supplies) would require the same elements of effective communication. Advance planning for effective and timely communication of these disasters is, indeed, an ounce of prevention that can produce a pound of cure.

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References

1. American Public Health Association: *National Preparedness Public Opinion Survey*, 2007. Available at *www.nphw.org/2007/pg_tools_poll.htm*. Accessed November 20, 2007.
2. Burton PW, Silver BD: The credibility of disaster evacuation warnings: The effects of issue framing and trust in government. *Annual Meeting of the American Political Science Association*. Philadelphia, PA, 2006.
3. Cooper C, Block R: *Disaster! Hurricane Katrina and the Failure of Homeland Security*. New York: Times Books, 2006.
4. Edwards F: Commissioner, California Seismic Safety Commission, 1991-1995, Site visits January 21-26, 1995; 2007.
5. Ding AW: A theoretical model of public response to the Homeland Security Advisory System. *J Disast Med Serv*. 2006; 3: 45-55.
6. Edwards F: Director, Office of Emergency Services, City of San Jose 1991-2006, 2007.
7. American Red Cross. *Talking About Disasters: Guide for Standard Messages*. Washington, DC: American Red Cross, 2006.
8. Lopes R: *Eleven C's of Community Disaster Education*. Washington, DC: American Red Cross, 2002.
9. American Red Cross: *Terrorism; 2007*. Available at *www.redcross.org/images/pdfs/code/terrorism.pdf*. Accessed November 20, 2007.
10. Centers for Disease Control and Prevention (CDC): Communicating in the First Hours: Initial Communication With the Public During a Potential Terrorism Event, 2007. Available at *www.bt.cdc.gov/firsthours/*. Accessed November 20, 2007.
11. Santa Clara County California Public Health Department: *Bioterrorism Information for Physicians: Zebra Pack, 1999*. Available at *www.sccgov.org*. Accessed November 20, 2007.
12. Santa Clara County California Public Health Department: *Pandemic Influenza Preparedness and Response Plan; 2007*. Available at *www.sccgov.org / sccsearch / ui.jsp*. Accessed November 20, 2007.

13. Manning FJ, Goldfrank L (eds.): *Preparing for Terrorism: Tools for Evaluating the Metropolitan Medical Response System Program.* Washington, DC: National Academy of Sciences, 2002.
14. Reuland M, Davies HJ: *Protecting Your Community From Terrorism: Strategies for Local Law Enforcement.* Washington, DC: Police Executive Research Forum, 2004.
15. Governor's Office of Emergency Services: San Francisco Bay Area Regional Emergency Coordination Plan, Appendix K, Bay Area Emergency Public Information Network Guide, 2007. Available at *http://www.oes.ca.gov/Operational/OESHome.nsf/PDF/Bay%20Area%20Regional%20Coordination%20Plan/$file/BARECPlan.pdf.* Accessed March 9, 2008.
16. Booth S, Hills-Evans K: Influenza pandemic preparation and response: A citizen's guide, Mid-Peninsula Citizens Preparedness Committee, 2007. Available at *http://www.newfluwiki2.com/upload/Citizen's%20Guide%20-%20Version%201.2.pdf.* Accessed March 9, 2008.
17. Edwards-Winslow F: Telling it like it is: The role of the media in terrorism response and recovery. In Kayyam J, Pangi R, (eds.): *First to Arrive: State and Local Response to Terrorism.* Cambridge, MA: MIT Press, 2003: 59-75.
18. Clarke C, Chess C, Holmes R, O'Neill KM: Speaking with one voice: Risk communication lessons from the US anthrax attacks. *J Conting Crisis Manag.* 2006; 14: 160-169.
19. Covello VT, Peters RG, Wojtecki JG, et al.: Risk communication, the West Nile virus epidemic, and bioterrorism: Responding to the communication challenges posed by the intentional or unintentional release of a pathogen in an urban setting. *J Urban Health.* 2001; 78: 382-391.
20. Sandman P. *Beyond panic prevention: Addressing emotion in emergency communication.* Atlanta, GA: Centers for Disease Control and Prevention, 2001. Emergency Risk Communication CDCynergy.
21. Bravata DM, Zaric GS, Holty J-EC, et al.: Reducing mortality from anthrax bioterrorism: Costs and benefits of alternative strategies for stockpiling and dispensing medical and pharmaceutical supplies. *Biosecur Bioterror.* 2006; 4(3): 244-262.
22. Zaric G, Brandeau M, Bravata D, Holty J-E, McDonald K, Owens D: Modeling the logistics of response to anthrax bioterrorism. *Med Decis Making* 2008.
23. Holty JE, Bravata DM, Liu H, Olshen RA, McDonald K, Owens DK: Systematic review: a century of inhalational anthrax cases from 1900 to 2005. *Ann Intern Med.* 2006; 144: 270-280.
24. U.S. Bureau of the Census: *Statistical Abstract of the United States.* Washington, DC: U.S. Department of Commerce, 2006.
25. Shepard CW, Soriano-Gabarro M, Zell ER, et al.: Antimicrobial postexposure prophylaxis for anthrax: Adverse events and adherence. *Emerg Infect Dis.* 2002; 8: 1124-1132.
26. Hupert N, Mushlin AI, Callahan MA. Modeling the public health response to bioterrorism: using discrete event simulation to design antibiotic distribution centers. *Med Decis Making.* 2002; 22 (5 suppl): S17-S25.
27. Centers for Disease Control and Prevention (CDC): Strategic National Stockpile. Available at *http://www.bt.cdc.gov/stockpile/index.asp.* Accessed June 7, 2007.
28. Centers for Disease Control and Prevention (CDC): *National Pharmaceutical Stockpile.* Available at *www.bt.cdc.gov/Documents App/NationalStockpile/national_pharmaceutical_stockpile.pdf.* Accessed August 17, 2003.
29. Bravata DM, McDonald K, Owens DK, et al.: *Regionalization of Bioterrorism Preparedness and Response (Evidence Report/Technology Assessment).* Rockville, MD: Agency for Healthcare Research and Quality, 2003.
30. Centers for Disease Control and Prevention (CDC). Receiving, Distributing, and Dispensing the National Pharmaceutical Stockpile: A Guide for Planners. Version 9 – Draft. Atlanta, GA, April 2002.
31. Higgins J, Cooper M, Schroeder-Tucker L, et al.: A field investigation of Bacillus anthracis contamination of U.S. Department of Agriculture and other Washington, D.C., buildings during the anthrax attack of October 2001. *Appl Environ Microbiol.* 2003; 69: 593-599.
32. Burnier M: Medication adherence and persistence as the cornerstone of effective antihypertensive therapy. *Am J Hypertens.* 2006; 19: 1190-1196.
33. Rueda S, Park-Wyllie LY, Bayoumi AM, et al.: Patient support and education for promoting adherence to highly active antiretroviral therapy for HIV/AIDS. *Cochrane Database of Systematic Reviews* 2006: 3.
34. Sorenson J. Risk communication and terrorism. *Biosecur Bioterror: Biodefense Strategy, Practice, Science.* 2004; 2: 229-231.
35. Santa Clara County California Public Health Department: Your Guide to Preparing for Pandemic Flu. San Jose, CA: Santa Clara County Public Health Department, 2006.