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Mass Casualty Prediction: By the Numbers

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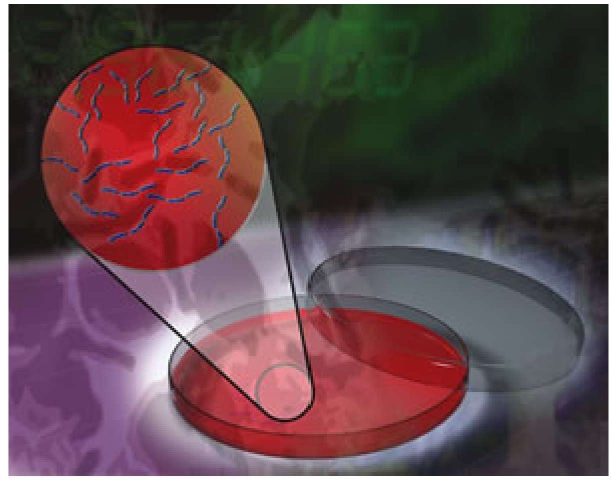

Can a methodological approach to predicting mass casualties during a biological attack of airborne anthrax be useful for response planning?

By Richard Hutchinson, Ph.D., Lieutenant Colonel George Christopher, M.D., Mohamed Athher Mughal, Ph.D., and Robert Gougelet, M.D.

The initial critically ill patients and fatalities immediately after a covert biological attack may provide valuable information to officials planning a medical response. For an effective and reasoned response, it is critical for officials to know how large the attack may be, how many fatalities and critically ill casualties may be expected and over what period of time they may occur. Ultimately, the answers to these questions will drive the scale of the response and medical emergency planning, including timely requisition of additional regional and federal resources.

Accurate predictions of casualties cannot be made because of the many unknown variables such as the inocula, the susceptibility of the population, the time the attack took place, and the specific characteristics of the agent such as particle size, dissemination efficiency and virulence. However, epidemiological investigation can provide an ongoing estimate of numbers of casualties as the crisis unfolds and emergency response proceeds.

The resulting information might be useful by providing “order of magnitude” estimates of total casualty numbers during the course of a biological incident involving a thousand or more casualties. Such estimates are key to assessing emergency response resource requirements for a bioterrorist attack. They are also useful for developing credible bioterrorist attack scenarios for emergency response analyses and exercises.

Anthrax as a Test Case

To provide a basis for emergency response planning as a part of the U.S. Army Soldiers and Biological Chemical Command’s (SBCCOM) Biological Weapons Improved Response Program (BW IRP), medical and biological weapons experts developed a template for the anticipated progression of anthrax in an exposed population. Subsequently, the template was reviewed and revised at the Operational Medicine Division, U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID). The revised template projected a more rapid onset of the disease associated with high inocula. The model assumes that increasing inocula are associated with decreasing incubation times and a more rapid progression from prodrome to critical illness. The model assumptions included a high inoculum and, consequently, a brief incubation (one to seven days), a brief prodrome (one to four days) and a rapid progression.

The USAMRIID model was verified with results from animal challenge experiments. In a study of inhalation anthrax in monkeys, the duration of prodrome of one to four days used in the USAMRIID model corresponds to the findings of the study that monkeys infected with inhalation anthrax were ill one to four days before death. Thus, the USAMRIID projections for rapid onset of anthrax in humans correlate with experimental findings in monkeys. Recently, the model assumption of a correlation between incubation time, the duration of the prodrome, and severity of illness was supported by the timeline of 10 of the 11 cases of bioterrorism-related inhalation anthrax that occurred in October and November 2001.

The largest number of actual human casualties infected with inhalation anthrax resulted from an accidental release of anthrax spores from a military installation in Sverdlovsk, Russia in 1979. Analysis of the data from the Sverdlovsk incident indicated a slow onset of disease, presumably associated with low dosage levels. The accident resulted in 66 fatalities and 11 that became ill but survived.

The number of critically ill, the cumulative number of fatalities, and the sum of these two for each day following the release on the first day were selected for analysis because they are directly observable during an incident.

Critically ill patients with unstable vital signs and respiratory distress would be presented to their primary health care providers and to hospital emergency rooms. They would then enter the community's medical system where medical specialists would evaluate their condition. Conversely, those in the prodromal stage develop non-specific symptoms and signs that cannot be readily differentiated from those of many common febrile illnesses. It is expected that patients with symptoms due to anxiety rather than infection will be presenting with those in the prodromal phase, which will further confuse the numbers of actual victims.

There is also a practical reason to focus on the number of critically ill—it is these patients that place the greatest demand on the medical system for care and treatment. The cumulative number of fatalities can likewise be tracked during an incident. While there will be confusion during a biological incident in accurately counting the numbers of critically ill and fatalities, these represent the most readily identifiable parameters. Therefore, they are the best available quantities upon which to make projections.

It is suggested that the USAMRIID casualty model and the casualty data from Sverdlovsk be used to anticipate the fastest and slowest progressions of inhalation anthrax. These extremes can be used to bracket what would likely happen in an actual biological event.

By looking at the data, when the number of critically ill begins to decrease, the total number of critically ill plus cumulative fatalities is about one-half of what it will ultimately be. Emergency managers and medical planners could potentially use this rule of thumb once the incident progresses to the point where the number of critically ill begins to decrease.

Further Numerical Analysis

For analysis purposes, an assumption must be made as to when the covert biological attack would be detected and a presumptive agent identified. Reasonably, the earliest day of detection would be during the third day after initial exposure, and it is likely that detection would occur before the end of the fourth. The same considerations should be applied to the casualty projections; in this case, the earliest that detection would likely occur is during the fourth day. At that time, the critically ill would approach 20 percent of the maximum level for the event. During the fifth day the number of critically ill would reach 50 percent of the maximum level. Thus, it is likely that the event would be identified by the end of the fifth day at the latest. This variation in detection timing was included in casualty projections since detection could occur anywhere in this range.

For a biological event involving less than 100 casualties, detection might occur several days later, particularly if surveillance systems are not in place to detect the event as soon as possible. In the case of Sverdlovsk, detection of the anthrax incident apparently occurred around the ninth day.

Variations will occur based on the manner of infection, for example when there is rapid onset of the disease associated with high dosage of spores. Here, the most highly infected would become critically ill and die before others with lower dosages reach the critically ill state.

During an incident, variation in the number of critically ill should be expected even with a single release of a noncontagious agent. Such variation might be mistakenly assumed to represent person-to-person transmission of disease or multiple releases. This undulation may also represent a window of opportunity—if the population at risk can be identified during the first wave, and given post-exposure prophylaxis, the second wave of casualties could be significantly reduced.

Factors can be calculated to project total fatalities and maximum number of critically ill based on tabular data. Based on those calculations, the following projections can be made as to the anticipated fatalities and critically ill:

• Twenty-four hours after detection of a probable anthrax medical situation, total number of fatalities will be between 1.4 and 6.2 (3.8 average) times the number of critically ill plus the cumulative number of fatalities at that time.

• Twenty-four hours after detection of a probable anthrax medical situation, the maximum number of critically ill at any time during the incident, will fall between 0.6 and 1.9 (1.3 average) times the number of critically ill plus the cumulative number of fatalities at that time.

Application of These Results

During an emergency response workshop held on April 29-30, 1999, participants addressed a scenario involving 10,000 people exposed to anthrax in a metropolitan area of 1 million people. This unannounced attack progressed as follows:

On June 7, 1999, 700 people presented flu-like symptoms. Most stayed at home, and the few that went to their physicians or hospitals were sent home to “rest, take flu medicine and drink plenty of liquids.” The following day, 2,700 additional people had flu-like symptoms, and 600 people reported critically ill to emergency rooms and clinics. One hundred people died by midnight of that day.

Expanded medical surveillance, epidemiological and law enforcement efforts were initiated during June 8 to determine the cause of the medical emergency. Anthrax was identified as the probable cause on June 9 and at the end of the day, the mayor asked for a projection of casualties. At that time there were 2,730 acutely ill and 670 fatalities.

The following projections were made by applying the above approximations:

• Total fatalities for the incident would likely fall between 5,000 and 21,000 with 13,000 being most likely. (Example calculation: Total number of fatalities would fall between 1.4 and 6.2 (3.8 average) times the number of critically ill plus the cumulative number of fatalities at that time which equaled 2,730 + 670 = 3,400.)

• The maximum number of critically ill would likely fall between 2,000 and 6,000 with 4,000 being most likely. (Example calculation: Maximum number of critically ill would fall between 0.6 and 1.9 (1.3 average) times the number of critically ill plus the cumulative number of fatalities at that time which equaled 2,730 + 670 = 3,400.)

The utility of these findings is to aid emergency managers and medical planners to extrapolate an estimated number of casualties based on the number of cases during the first days of an anthrax epidemic. The model is based on the assumptions that the durations of the incubation and prodrome are inoculum dependent, with higher inocula resulting in compressed incubation times and progression to critical illness, and that if the incubation time is known, the duration of the prodrome can be estimated. The model does not factor independent variables such as age and underlying health of the exposed individuals, or differential inoculation based on distance from the release, climatic conditions, the numbers of people exposed, population density, and the availability and effectiveness of intensive care. While the above projections have a wide range, they do bracket the practical scope of the problem.

Emergency managers and medical emergency planners can use these estimates to assess medical and other resource requirements during a bioterrorist attack. State, local and federal emergency managers as well as medical planners can use these estimates to develop technically credible attack scenarios for emergency response exercises and analyses. Although focused on anthrax here, using a similar approach, casualty projection rules of thumb can be developed for other potential biological agents.

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