Being Prepared: Modeling the Response to an Anthrax Attack

On 1 February 2005, Connecticut residents heard an emergency alert broadcast, beginning at 2:10 p.m. and ending at 3:10 p.m., that ordered them to evacuate the state. Fortunately, their response was minimal. A state emergency management official had mistakenly entered the wrong computer code into a weekly test of the emergency alert system, and incredulous Connecticut residents had correctly assumed that the broadcast was a false alarm. The incident illustrates several difficulties in preparing for a future catastrophe. Potential catastrophes differ in form, scale, and predictability, and each requires specific consideration of risk and preparation. If we could predict with certainty when and where a particular catastrophic event would occur, we could prepare with total commitment. Alas, to quote the physicist Niels Bohr: "Prediction is very difficult, especially about the future" (1).

In this issue, Fowler and colleagues (2) analyze the issues of preparedness for a specific potential catastrophe: a large-scale anthrax attack on a U.S. city. They focus on medical logistics and cost-effectiveness analyses of preattack and postattack strategies. Their method is decision-analytic modeling, which uses computer simulations to predict large-scale system outcomes based on assumptions about the probability of small-scale events. The model tracks individuals as they pass through various health states. Transition from one state to another is a matter of chance, as determined by probabilities derived from published studies. The mathematical modeling allows comparison of different strategies of preparation and response in terms of probabilities of vaccination, vaccination efficacy, and side effects; antibiotic therapy efficacy and side effects; and costs of hospital care and long-term medical care of individual patients. Other researchers have developed mathematical models of anthrax attacks. A recent model predicted more than 100 000 deaths would occur in a city of 10 million people attacked with a release of 1 kg of anthrax spores, even with relatively efficient postattack medical response (3).

The setting in Fowler and colleagues' study (2) is a U.S. city of 5 million people targeted with the release of enough aerosolized *Bacillus anthracis* spores to expose 10% of the population. Fowler and colleagues assume that 95% of exposed individuals will develop life-threatening disease unless they receive emergency postattack prophylactic intervention. They assume, on the basis of other studies, an annual probability of attack of 1% in each year of an extended period of time into the future. They compare 2 preattack strategies (mass vaccination or no mass vaccination) and 3 postattack strategies (emergency distribution of prophylactic antibiotics, prophylactic vaccination, or both).

The most cost-effective postattack strategy is implementation of prophylactic vaccination and prophylactic antibiotics immediately after exposure. Fowler and colleagues assume that both measures reduce the incidence of severe anthrax disease after exposure (by 45% and 80%, respectively). Their surprising and important claim is that this postattack strategy of emergency medical intervention is more cost-effective without the preattack mass vaccination. Fowler and colleagues base this claim on assumptions about the annualized probability of attack, cumulative costs of mass vaccination, medical costs of serious adverse vaccine reactions, the speed of dispensation of medical resources after an attack, and the effectiveness of postexposure prophylactic measures. They emphasize that this claim depends on their baseline probability of attack (1% per year) and their assumption that the adverse effects of the vaccine outweigh its potential benefit until the individual probability of exposure reaches 1 in 200.

Fowler and colleagues do an excellent job of modeling the policy issues for 1 city, but this focus is a limitation of their analysis. Their model and other models (3–5) that quantify large-scale anthrax attacks are important for policy planning, but they may underestimate the incalculable societal impact of such an attack. Would social panic and civil chaos result if a true alarm were broadcast to a large city? Would the medical infrastructure disintegrate from lack of organization, personnel, facilities, equipment, and supplies? What would be the cost of evacuating and decontaminating the city? The decontamination of the U.S. postal facilities in Brentwood, Washington, DC, and Hamilton Township, New Jersey, after the 2001 mail anthrax attack required more than 2 years and cost more than $200 million (6). The amount of anthrax spores involved in the Brentwood attack (<1 g) was minute compared with the release of spores from a large-scale attack. The only way to avoid these enormous costs is to avoid attack altogether. Fowler and colleagues did not consider the possibility that terrorists would not attack a city that they knew had vaccinated its inhabitants.

Fowler and colleagues' exclusive focus on policymaking in 1 city may not be realistic for another reason: Both preattack and postattack policy for all U.S. cities depends on U.S. federal government policy. The federal government, under the Project BioShield Legislation of 2004, will stockpile 75 million doses of anthrax vaccine (sufficient for emergency vaccination of 25 million people) to the Strategic National Stockpile by 2007 (7). It is improbable, logically and politically, that the federal government would select only 1 or few U.S. cities for preattack mass vaccination. An anthrax-armed enemy could simply target cities that had not implemented preattack mass vaccination. We must view vaccination in the context of the available supply of vaccine in the Strategic National Stockpile and the potential of mass vaccination of the entire U.S. population to deter an attack on all U.S. cities. Vaccination has its own risk, and if even a very small fraction of 1% of the

U.S. population experienced serious illness or death from side effects of the vaccine, the toll would be daunting. But, if a large-scale attack occurs, with tens of thousands or hundreds of thousands of deaths, the societal trauma would almost certainly compel the federal government, as defense against further attacks, to accelerate vaccine production and vaccinate the entire U.S. population, regardless of costs. Perhaps only after experiencing the devastation of an attack can we confront the reality of the measures necessary to avoid it.

Fowler and colleagues emphasize that rational preparation for a large-scale anthrax attack ultimately depends on the probability that it will occur. The probability of attack, however, is the most difficult variable to predict, and its value is subject to abrupt change as the world situation changes. Fowler and colleagues' in-depth analysis for an assumed low level of risk strongly supports the current U.S. policy of postattack medical response rather than preattack mass vaccination. At the current level of risk for attack, measures (such as implementation of technology to detect the release of anthrax spores; organization of medical logistics; stockpiling of emergency supplies in the Strategic National Stockpile; and scientific research into the development of vaccines, antibiotics, and antidotes) are imperative. But at the current level of risk for attack, mass vaccination of the entire U.S. population is unwarranted because of the clinically significant adverse side effects of the vaccine. If the risk for attack sufficiently increases, however, preattack mass vaccination of the entire U.S. population may be the most rational strategy to prepare for a large-scale anthrax attack and the most hopeful policy to render anthrax ultimately ineffective as a weapon of mass destruction.

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References

1. **Petersen A.** The philosophy of Niels Bohr—1885-1962. Bull At Sci. 1963; 19:8-14.
2. **Fowler RA, Sanders GD, Bravata DM, Nouri B, Gastwirth JM, Peterson D, et al.** Cost-effectiveness of defending against bioterrorism: a comparison of vaccination and antibiotic prophylaxis against anthrax. Ann Intern Med. 2005;142: 601-10.
3. **Wein LM, Craft DL, Kaplan EH.** Emergency response to an anthrax attack. Proc Natl Acad Sci U S A. 2003;100:4346-51. [PMID: 12651951]
4. World Health Organization. Health Aspects of Chemical and Biological Weapons: Report of a WHO Group of Consultants. Geneva, Switzerland: World Health Organization; 1970.
5. U.S. Congress Office of Technology Assessment. Proliferation of Weapons of Mass Destruction: Assessing the Risk. Report no. OTA-ISC-559. Washington, DC: U.S. Government Printing Office; 1993.
6. **Webb GF.** A silent bomb: the risk of anthrax as a weapon of mass destruction. Proc Natl Acad Sci U S A. 2003;100:4355-6. [PMID: 12682291]
7. **Kaufman M.** U.S. awards anthrax vaccine deal. The Washington Post. 5 November 2004:A4. Accessed at www.washingtonpost.com/wp-dyn/articles /A26564-2004Nov4.html on 2 March 2005.