A mathematician at Vanderbilt and an expert in infectious diseases at the New York University School of Medicine have teamed up to produce a mathematical model of how anthrax can be spread through the mail.

The model, which appears in the May 14 issue of the Proceedings of the National Academy of Sciences, simulates the recent outbreak of mail-borne anthrax deaths in the United States and demonstrates that all the known cases of infection can be explained by contamination spread through the mail from six original envelopes.

The analysis concludes that original anthrax-filled envelopes must have contaminated an additional 5,000 pieces of mail with significant but much lower levels of anthrax spores in order to account for the two deaths that appear have occurred from such cross-contamination. In the case of any future attacks of this type, the model provides a framework that can be used for the rapid identification and containment of any further outbreaks.

The model was developed by Glenn F. Webb, professor of mathematics at Vanderbilt, and Martin J. Blaser, the Frederick H. King Professor of Internal Medicine, chairman of the department of medicine and professor of microbiology at the NYU School of Medicine.

By David F. Salisbury
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Mail-borne anthrax model: research details

\[ G[m]_{k1} = N \sum_{m1=1}^{m-1} c[m1]_{k1} , k=2,3,4 \]
Mail-borne anthrax model

The new mathematical model of how anthrax spores can spread through the mail system was the result of a long standing collaboration and friendship between Glenn Webb and Martin Blaser that began while Blaser was working at the Vanderbilt Medical Center.

Because of his background in infectious diseases and his role as chairman of medicine at NYU, Blaser was tapped in the days following the Sept. 11 terrorist attacks by New York Mayor Rudy Giuliani to participate in a small task force on bioterrorism. "The mayor asked us what he should be worrying about, and several of us told him ‘anthrax’ because, compared to other infectious diseases, it's relatively easy for terrorists to use to cause harm," says Blaser.

Last October, following news that envelopes filled with anthrax spores had been mailed to several government officials and journalists, Blaser became involved in the investigations of the cases that took place in New York. "Initially all the cases were related to mail. Then there was the case of the woman in the Bronx, which no one could figure out, and the apparently unrelated case of the woman in Connecticut two weeks later," says Blaser. "At that point I figured out that it's got to be mail and it's got to be a cross-contamination model."

Airborne versus mail-borne

Blaser bounced his ideas off Webb and the two agreed to try to develop a mathematical model that adequately explains the basic facts of the fall outbreak based on cross-contamination. The model would not prove that contaminated letters caused all the cases, but it would demonstrate that the explanation is feasible, the scientists say. (The other hypothesis that has been proposed for the apparently unrelated deaths is that the victims were infected by anthrax spores carried downwind from contaminated postal facilities.)

"It was a very exciting and interesting project," says Webb. "It was unlike anything I had ever done before because it was such a rapid production. We thought the subject was very timely and knew we had to move quickly."

Eighteen cases of anthrax infections have been reported since last October. Eleven were caused by inhalation of anthrax spores and seven were caused by cutaneous (skin) contact. Five of the people who inhaled anthrax have died: a photo editor in Florida, two postal workers and two women who had no apparent association with the original letters. The federal task force investigating the cases reports that four of the original letters have been recovered and officials involved have stated publicly that they believe at least two additional anthrax-laden letters passed through the postal system that have not been found.
Mail-borne anthrax model

Model tracks contaminated letters through the postal system

The mathematical model tracks contaminated letters through different "nodes" in the postal system. The first node is the point at which the letters enter the system, either mailbox or post office. Then the letters move to local postal stations. From there they are transported to regional stations and back to local stations before they are delivered. Each of the nodes is assigned a different level of risk of spreading anthrax spores depending on how the letters are handled.

In particular, the model focuses on how the spores can leak from the original envelopes as they pass through the high-speed sorting machines used in the regional postal facilities and can contaminate hundreds to thousands of other letters passing through the facility at the same time. “A plausible mechanism for release of the spores from the interior of an envelope is the bellows action of the processing machines, which may draw spores on or into following envelopes,” they state.

The scientists found that the model provides the best match for the fall outbreak when they assume that there were six original letters, each carrying trillions of anthrax spores. They calculate that these letters, although tightly sealed, contaminated about 5,000 other letters with much smaller numbers of spores, ranging from 10 to 10,000 apiece.

5,000 people may have received contaminated letters

This suggests that 5,000 recipients received cross-contaminated letters but the contamination level was so low that the exposure proved lethal in only two cases. It was probably no accident that the two victims were elderly. Evidence based on an accidental anthrax release in 1979 in Russia suggests that the fatality rate among the elderly is considerably higher than it is among the young and middle-aged, the researchers point out.

"What is very striking is that only one of the deaths was the recipient of an original letter,” says Webb. “The much greater danger is to postal workers and to the recipients of cross-contaminated letters. So the threat is much greater than what people believed earlier.”

If their model is correct, "the rapid and widespread usage of antibiotics among postal workers and persons in the immediate environment of the received original letters probably averted a substantial number of cases," Blaser and Webb write. They suggest that vaccination of all postal workers and other professional mail-handlers may be desirable in view of the scale of the potential problem.

In the case of another mail-borne outbreak of anthrax, the model provides a framework that can be used to figure out what is going on more rapidly than would otherwise be possible. "If, God forbid, there were another outbreak and cases started turning up in different localities, the model could be used to work backwards to identify the groups of people who need to receive antibiotics or vaccine," Blaser says.

Biographical sketch
Mail-borne anthrax model

Glenn Webb is a world authority on the application of mathematical theory and methods to the study of populations. These can be populations of objects, like letters, or of living things such as cells, genes and biomolecules.

As a boy growing up in Miami, Florida, Webb didn't have any idea of becoming a mathematician. He dreamed of being a great explorer instead. His mother and his father, who was an insurance salesman, put great emphasis on the importance of education. As a result, he and his two brothers all went to college and got advanced degrees. One of his brothers works at NASA's Jet Propulsion Laboratory in Pasadena and the other is a lawyer.

When he was accepted as a freshman at the Georgia Institute of Technology, Webb intended to become an engineer. But he soon found that he liked mathematics better.

Webb specialized in the study of differential equations. These are the fundamental equations underlying calculus. Because they can describe the way that dynamic systems change, they are widely used in all the sciences. After getting his masters and doctoral degrees from Emory University in 1986, Webb accepted a position at Vanderbilt, where he has remained ever since.

His initial research was extremely theoretical. It required an advanced knowledge of differential theory to appreciate. However, he found himself increasingly attracted to more practical and applied studies, particularly involving problems in biology and medical science.

In addition to using his talents to help solve practical problems like how infectious diseases spread, Webb finds a real psychic reward from solving really difficult problems, problems that can take months, even years of effort to master.

Related links

Glenn Webb's home page

Martin Blaser's home page

CDC background on mail-borne anthrax

FBI "Amerithrax" web site

Full U.S. coverage of anthrax mailing investigation