Testing new predictive models involving biological warfare attacks on civilians

Walter R. Schumm, PhD and Farrell J. Webb, PhD
School of Family Studies and Human Services
Justin Hall, Kansas State University
1700 Anderson Avenue
Manhattan, KS 66506-1403 USA
Phone: +1 785 539 3641 (home) +1 785 532 1494 (office)
Fax: +1 785 532 5505
Email: Schumm@ksu.edu (work) WRSchumm@aol.com (home)
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Abstract

Walden and Kaplan (2004) and Brookmeyer, Johnson, and Bollinger (2003) have recently used complex mathematical models to predict projected infections and fatalities, respectively, from biological warfare anthrax attacks on civilians. Their models have been based, in large part, on the events at Sverdlovsk when anthrax spores were released by mistake from a Soviet facility in 1979. Dr. Brookmeyer, when contacted by the senior author, provided a revised table of predictions, since his original published table had included substantial errors. Here, the new models' predictions are validated against the anthrax epidemic that occurred at the Arms Mill in Manchester, New Hampshire in the autumn of 1957. The models predicted approximately 8 infections and 5 deaths. Nine infections occurred, providing support for the Walden and Kaplan (2004) model. Given that 4 deaths occurred with one death prevented only by timely administration of antibiotics, the mortality outcome also provides support for Brookmeyer et al.'s (2003) statistical modeling. Thus, both models appeared to predict the outcomes of the relatively small epidemic at Manchester with adequate accuracy. Whether the models would accurately predict the outcomes of much larger attacks is yet to be determined.

Keywords: Anthrax, Models of Biological Warfare, Predicting Casualties

1. Background

During the recent anthrax letter attacks, the number of days between exposure to aerosolized anthrax spores and the onset of disease ranged between four and six days for those exposed in New Jersey and Washington, D. C. [1]. Without treatment, death occurs within a few days of onset in most cases of inhalational anthrax [2]. In the Sverdlovsk (Soviet Union) anthrax outbreak in the spring of 1979, onset among fatal cases occurred as soon as two days after exposure but the modal number of days was between five and eight, with an estimated median of eleven days and a mean of just over fourteen days [2]. Using a likelihood function with truncated data, Brookmeyer et al. [2] developed a formula and table predicting the number of lives that could be saved by timely public health intervention given the number of deaths from anthrax occurring within a given number of days of exposure to inhaled anthrax spores. Table 1 in Brookmeyer et al. [2: 244) allowed visual estimation of total number of deaths without public intervention given the number of fatal cases (X) occurring within T days following release of the pathogen, with X ranging between 5 and 100 and T ranging between 5 and 20.

More recently, Walden and Kaplan [3] have published a model for predicting estimated total cases of anthrax infection, providing a simplified table that allows readers to estimate total cases of infection expected from the number of cases observed between the first and fifth days of the attack.

2. Method

First, we collected the data from previous research [4,5,6] on the cases of inhalation anthrax observed during the Manchester epidemic, as provided in Table 1 below. Table 1 contains data on the initials of the workers infected, characteristics of each worker, the date of onset of the anthrax infection, and the date of death, if applicable. As shown in Table 1, the first case of anthrax infection in Manchester occurred on August 27, 1957 and the second case occurred five days later on 1 September.

Secondly, we noted that Walden and Kaplan [3] provide a table in which the number of cases observed in the first five days of an attack can be used to estimate the total number of cases expected before the rate of infection subsides. In their table, they indicate that if 23 cases have occurred by day five, the total number of cases estimated would be 90.

Thirdly, the first author requested that Brookmeyer et al. [2] expand their Table 1 [2:244] to include three and four cases (X) in order to evaluate the validity of their statistical procedures against what actually occurred in the Manchester, New Hampshire epidemic in the fall of 1957, as described in detail elsewhere [7,8]. Dr. Brookmeyer, as noted in Table 2 below, indicated that the published data [2] contained numerous errors; he provided a revised, more accurate table, as well as expanding it to include a smaller number of cases, as had been requested. Table 2 below contains Dr. Brookmeyer's revised and expanded predictions.

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However, to use Brookmeyer et al.'s [2] table effectively, an estimate of the date of exposure is needed. The earliest onset of disease in Manchester occurred on August 27th, a Tuesday. Given that the earliest onsets in Sverdlovsk occurred after two days, with a mode of 5 to 8 days, and that those exposed in the letter attacks in the United States in 2001 developed onset between 4 and 6 days after exposure, it is likely that exposure occurred the previous work week, most likely between August 19 and 23. The bale of goat hair (321-B) suspected of containing anthrax that infected the workers was opened early in the week and reached the carding and combing departments in the middle of the week, probably about August 21st. The first workers (TT and AJ) who died were from the carding and combing departments. If so, that would yield approximately 17 days after exposure on September 6th, 19 days after exposure on September 8th, and 24 days after exposure on September 13th. The days after exposure (T) and the total number of deaths (X) observed by so many days after exposure are needed in Table 2 below in order to predict the total estimated number of deaths.

3. Results

The second case of anthrax in Manchester occurred on the fifth day after the first case, for a total of two cases by the fifth day. Walden and Kaplan [3] predicted a total of 90 infected cases if 23 cases had occurred by the fifth day. By extrapolation, we would have predicted 2/23 (8.7%) of 90 cases to have occurred in Manchester, using their model – or approximately eight cases total. In Manchester, five cases of inhalation anthrax occurred, along with four cases of cutaneous anthrax, for a total of nine cases. Therefore, the Walden and Kaplan [3] model fits the actual Manchester outcomes to a reasonable degree.

Turning to Brookmeyer et al.'s [2] model, Table 3 below illustrates what a public health official would have observed and predicted, given Table 2, and the unfolding cases of anthrax infection during the Manchester epidemic. The last worker who died of inhalation anthrax probably represents a statistical outlier in the model, similar to those that occurred in the Sverdlovsk outbreak, in which some individuals did not experience onset of the disease until 40 days after the release of the pathogen. Hence, Table 3 focuses on the first four inhalation cases.

The Brookmeyer et al. [2] model predicts four to five deaths as shown in Table 3, with one or two additional cases of inhalation anthrax that could have been saved with prompt antibiotic treatment. Three deaths occurred immediately, with a fourth later on (worker AL). Worker LL survived the epidemic because of antibiotic treatment (and probably a strong constitution). Worker AL was given antibiotic tablets to consume, but it is not clear whether he complied with his prescription, not being aware of the full nature and seriousness of his illness (his doctor told him he had only an Asian flu, for which antibiotics were not a useful treatment since the flu is a virus, not a bacteria; antibiotics would have been useful only for preventing a secondary bacterial infection). Thus, there was at least one and possibly two preventable deaths during the Manchester epidemic. Since the predicted deaths and the predicted preventable deaths are quite close to the actual deaths and actual preventable deaths, it appears that the Brookmeyer et al. [2] model works reasonably well when tested with data from the 1957 Manchester epidemic.

4. Conclusion

Both models [2,3] appear to predict, with reasonable accuracy, the outcomes for infections and fatalities in the Manchester anthrax epidemic of 1957 (keyed to the 1979 anthrax outbreak in Sverdlovsk). Therefore, both models would appear to work well for low level biological anthrax attacks. Whether the models would work as well for much larger scale attacks remains to be determined; however, it is something which we hope would never have to be examined other than theoretically.

References

[1] Brookmeyer R, Blades N. Prevention of inhalational anthrax in the U.S. outbreak. Science, 2002;295:1861.
[2] Brookmeyer R, Blades N, Hugh-Jones M, Henderson DA. The statistical analysis of truncated data: application to the Sverdlovsk anthrax outbreak. Biostatistics, 2001;2:233–47.
[3] Walden J, Kaplan EH. Estimating time and size of bioterror attack. Emerging Infectious Diseases, 2004;10:1202–5.
[4] Brachman PS, Gold H, Plotkin SA, Fekety R, Werrin M, Ingraham NR. Field evaluation of a human anthrax vaccine. American Journal of Public Health, 1962;52:632–45.
[5] Brachman PS, Plotkin SA, Bumford FH, Atchison MM. An epidemic of inhalation anthrax: the first in the twentieth century. II. Epidemiology. American Journal of Hygiene, 1960;72:6–23.
[6] Plotkin SA, Brachman PS, Utell M, Bumford FH, Atchison MM. An epidemic of inhalation anthrax, the first in the twentieth century. I. Clinical features. American Journal of Medicine, 1960;29:992–1001.
[7] Schumm WR, Brenneman RL. How adequate and well-controlled was the clinical trial of a human anthrax vaccine, 1955-1959? Medical Veritas, 2004;1(2):166–70.
[8] Schumm WR, Brenneman RL, Arieli B, Mayo-Theus S, Muhammad J. A statistical reanalysis of Brachman et al.'s (1962) study of a human anthrax vaccine. Medical Veritas, 2004;1(2):171–8.

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Table 1. Dates of onset and death for five mill workers at the Arms Mill, Manchester, New Hampshire, 1957.

Initials of Worker	Characteristics of Worker	Date of Onset	Date of Death
TT	60 year old white male who had worked at Mill since 1941, most recently as a noil remover in the combing department.	27 Aug.	30 Aug.
AJ	49 year old white male who had worked at Mill since June 1956, as a card-fixer in the carding dept.	1 Sept.	6 Sept.
EC	65 year old white female who had worked at Mill since 1946 as a bobbin cleaner in the weaving department.	2 Sept.	8 Sept.
LL	46 year old white male who had worked at Mill since October 1955 as a card tender in the carding department.	9 Sept.	Survived but without antibiotic treatment would probably have died on 13 Sept.
AL	33 year old white male who had begun working at Mill on August 26, 1957 as a noil remover in the combing department.	30 Oct.	3 Nov.

Table 2. Estimated number of deaths ($X/F_d(T)$) from an anthrax outbreak in the absence of any public health intervention if a cumulative number of X deaths are observed within T days following release of the pathogen. Calculations are based on a lognormal distribution for F_d with median $\exp(\mu) = 15.8$ days and dispersion factor $\exp(\sigma) = 1.70$.

Number of cases (X)	Days (T) 5	10	15	20	25
2	133	10	4	3	2
3	199	15	7	4	3
4	265	21	9	6	5
5	332	26	11	7	6
10	664	51	22	15	
20	1327	103	43	30	
30	1991	154	65	45	
40	2655	206	87	60	
50	3318	257	108	74	
60	3982	309	130	89	
70	4646	360	152	104	
80	5310	412	174	119	
90	5973	463	195	134	
100	6637	515	217	149	

Note: Values for T = 25 are estimated by the author as they were not provided by Dr. Brookmeyer. Table 2 represents a revision of Table 1 (Brookmeyer, Blades, Hugh-Jones, & Henderson, 2001, p. 244) provided by Dr. Brookmeyer on April 24, 2004 to Dr. Schumm by e-mail.

Table 3. Application of Table 2 predictions to Table 1 information to assess accuracy of statistical methodology

Date of Most Recent Death (from Table 1)	Total Deaths (from Table 1)	Expected Deaths without Treatment (from Table 2)	Preventable Deaths
September 6 (17 days from exposure)	Two	Four	Two
September 8 (19 days from exposure)	Three	Four to Five	One to Two
September 13 (24 days from exposure)	(Four)	Four to Five	One

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