Responding to Bioterrorist Smallpox in San Antonio

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We used discrete-event simulation to help the San Antonio public health and acute medical care communities to plan their response to a bioterrorist attack. The analysis, based on a scenario positing an attack with aerosolized smallpox, indicated the resources and strategies needed for an effective response. We found that a mixture of public-health measures designed to stop the spread of the disease would form a more robust and effective response than any single measure. However, unless the attack is very small, the public-health system is unlikely to be able to prevent a surge in demand for acute care that will require community-wide coordination of resources, a definitive patient-triage policy, and temporary treatment practices. The San Antonio communities are integrating our recommendations into their plans.

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The Centers for Disease Control and Prevention (CDC) classifies smallpox (variolae major) as a Category A bioterrorism agent (CDC 2004). Although it was eradicated as a naturally occurring disease, laboratory samples exist in the United States and Russia. The World Health Organization (WHO) recommended that general vaccination be discontinued in every country in its final report on the eradication of smallpox (WHO 1980). Vaccination of the general public ceased in the 1970s, and the CDC estimates that the current population has very little immunity. Government, public-health, and emergency-response planners and decision makers are still concerned about smallpox, and a single case would threaten a worldwide epidemic.

Background

Smallpox was eradicated as a naturally occurring disease through a worldwide effort led by WHO that began in 1967. The last natural smallpox case occurred in Somalia in 1977, and WHO certified its eradication in 1979. The laboratory samples in the United States and Russia were originally scheduled for destruction in 2002 but are maintained for continuing research (WHO 2002). Given the certified eradication, a smallpox case today could develop only from an infection by the variola virus held in storage (Fenner et al. 1988).

Smallpox has an incubation period of approximately 12 days. Toward the end of the incubation period, victims experience a prodromal period characterized by high fever but are not yet infectious. Following the prodromal period, smallpox becomes highly infectious: within a household of unvaccinated people, the disease is likely to be transmitted from an infective person to susceptible persons. The disease can also be transmitted through casual contact, although the likelihood of transmission during a single contact is quite low.

Effective vaccination of a susceptible individual prior to contact with an infective person reduces the probability of disease transmission by an order of
magnitude. The disease can still be transmitted to a vaccinated person, but it is not likely in a household and nearly impossible via casual contact.

The smallpox vaccination works more quickly than the disease. If a person is vaccinated within a few days after being infected with smallpox, the vaccination may lessen the severity of the disease or may abort the disease altogether. An effective public-health program to vaccinate those who have had contact with an infective person may lower the morbidity of new victims and, if new victims are not isolated, will somewhat lessen the likelihood that they will transmit the disease to future contacts (Fenner et al. 1988).

A public-health system could respond to a bioterrorist smallpox attack with ring vaccination, mass vaccination, or quarantine. In ring vaccination (or trace and immunize), health officials try to find and vaccinate the recent contacts of an infective person during the few days in which vaccination will modify or abort the disease. In contrast, in mass vaccination, they try to immunize an entire population. With quarantine, they try to isolate an exposed individual from the unexposed population until they deem him or her not infective.

Analysts have used several epidemiology models to investigate the effectiveness of these responses. Koopman (2004) classified these models into three types: simple deterministic compartmental models, discrete individual models (which also maintain compartments of individuals), and network models. Models may also be differentiated by their representation of homogeneous or heterogeneous mixing within the population (Ferguson et al. 2003).

Simple deterministic compartmental models, which Koopman (2002) termed continuous population models, may be based on differential equations (Kaplan et al. 2002, 2003) or on difference equations (Kress 2004). These models are easier to analyze than discrete individual models but cannot capture the chance effects that cause an invasion of a disease to fail. The models may represent homogeneous mixing (Kaplan et al. 2002, 2003) or heterogeneous mixing in households, social groups, and the general population (Kress 2004).

Discrete individual models are stochastic and are appropriate for investigating the initial contact and disease-transmission processes between infective and susceptible persons within a population. These models can assume homogeneous mixing to study epidemics in national populations (Bozzette et al. 2003) or heterogeneous mixing, which allows the study of the initial infections within a community (Halloran et al. 2002).

Network models, such as those of Keeling (1999) and Porco et al. (2004), describe fixed linkages representing patterns of contact within a population, where a network that consists of a limited number of connected pairs affects the dynamics of infection within the population. These models represent the dependencies between contacts and between linkages, whereas the previous model types assume independence (Koopman 2004). Watts and Strogatz (1998) describe “small world” networks, created by stochastically altering “regular” networks to introduce increasing disorder, and their effects on the spread of infectious diseases. Eubank et al. (2004) describe the combination of a large-scale urban-traffic simulation to generate dynamic bipartite graphs with parameterized models of disease transmission and progression to study the effects of vaccination and quarantine on the development of smallpox epidemics.

The nature of the contact between an infective individual and a susceptible individual affects the likelihood that a disease is transmitted. In smallpox transmission, “the overwhelming majority of secondary infections occurred in close family contacts of overt cases of smallpox, especially in those who slept in the same room or the same bed. Next in frequency were those who lived in the same house; residents of other houses, even in the same compound were much less likely to become infected” (Fenner et al. 1988, p. 191). Therefore, for our epidemiology model, the casualty prediction model (CPM), we used a discrete individual model with heterogeneous mixing that distinguishes household contacts from casual contacts.

While many epidemiology models have been used to study disease transmission and the effects of alternative public-health actions on the development of epidemics, we did not uncover models that translate the effects of public-health actions into effects on the health-care infrastructure. The health-care complex model (HCM) is such a model and, when coupled
with the CPM, can address the ability of the public-health system and the acute health-care delivery system to respond.

Methods

We applied our two models in the context of the population, public-health capabilities, and health-care infrastructure of San Antonio, Texas. We studied the effects of each public-health remediation strategy in isolation, and we also examined some combinations of strategies. We presented the results to local public-health and emergency preparedness leaders and incorporated their feedback into a hypothetical smallpox-attack scenario. We used the stream of victims in that scenario combined with the resource constraints of the San Antonio health-care infrastructure to investigate potential surges in acute care needs. The two generic models have been used to represent other diseases and locations (Miller et al. 2004).

The Casualty Prediction Model

The CPM is a PC-based discrete-event simulation that represents contacts and disease transmission between infective and susceptible individuals (Appendix). Its output is a time history of the number of individuals infected.

The CPM represents the transmission of disease to a susceptible individual, followed by an incubation period, a prodromal period (if appropriate for the disease simulated), and an infectious period. During the infectious period, the infective individual contacts susceptible individuals, some of whom become infected. Each such infection produces another time line for the newly infected individual. The process of contact and transmission continues until the original infective individual seeks medical care. (While a patient may still be infectious after obtaining care, we assumed that standard precautions prevent the spread of the disease while the patient is under medical care.)

The CPM also represents several actions public-health organizations might take to halt a smallpox epidemic, including vaccination, actions to affect the nature and frequency of contacts between infective and susceptible individuals, and isolation of infective victims.

Vaccination is important for a successful public-health response to a smallpox outbreak because immunity is uncommon in the general population. The CPM can model both ring- and mass-vaccination strategies, singly or in combination. The vaccination status of infective and susceptible individuals affects the probability of transmission during contact. The infective carries vaccination status as an attribute, and the susceptible individual’s vaccination status is dynamically determined at the time of contact based on the time, the type of vaccination program, and its performance parameters. Disease transmission varies greatly with the nature of the contact, and the CPM discriminates between household and casual contacts.

In a public-health emergency, such as a bioterrorist attack using weaponized smallpox, the behavior of the population would likely change, reducing the number of casual contacts an infective person might have with susceptible persons. Such a reduction in casual contacts might result from public-health initiatives, such as public announcements and quarantine of infected individuals. The CPM allows analysts to represent such effects by reducing casual contacts over time or removing infective individuals from the population of susceptible individuals.

Like other epidemiology models, the CPM can be used as a stand-alone tool to investigate the effect of alternative public-health interventions or to conduct sensitivity analyses of the impact of variations in parameter values, such as the initial number of victims, contact rates, the start dates of various interventions, and vaccination effectiveness. However, analysts can also use the model in conjunction with the second model to obtain outputs describing morbidity, mortality, and resource consumption associated with the treatment of these patients.

The Health-Care Complex Model

The second model, the HCM, is a PC-based discrete-event simulation that represents health-care delivery at the patient-episode level throughout a network of medical facilities (Appendix). The model represents patients’ arrival at each hospital or clinic within a network and employs a set of input clinical protocols to describe each patient’s diagnosis and treatment. The protocols specify the medical resources required for each step in the diagnosis and treatment, and the
model simulates use of these resources at the facilities within the network. The HCM tracks resource utilization and patient outcomes (including mortality) and can be used to identify bottlenecks in care delivery.

Patients are input to the model using output from the CPM. Each patient appears for diagnosis and treatment at one of several medical facilities. The facilities are characterized by available resources, including providers by type, beds by type, and various ancillary resources. The model uses treatment protocols linked to the patient’s condition, age, and vaccination status to identify the resources needed for each service within the diagnosis and treatment. The model compares the resources required for a given service and either (1) provides the service immediately if all needed resources are available, (2) requires the patient to wait until the needed resources become available, or (3) transfers the patient to another facility where the needed resources are available. This process continues until the patient is released from the acute-care system, dies, or is transferred outside the community because of a lack of needed resources. The model records resource consumption, patient wait times, patient disposition, and other information for subsequent analysis.

For this analysis, the CPM generates daily arrivals to the HCM in each of several categories. The first category, prerecognition, takes the patient through a treatment protocol representing normal diagnostic and treatment services. Morbidity and mortality correspond to those for unvaccinated victims. The second, postrecognition unvaccinated, assumes truncated diagnostic and presumptive treatment services with similarly high morbidity and mortality. The third, vaccinated, has lower morbidity and mortality. Each smallpox protocol is specific to one of five age groups and differs in the type and amount of resources required for a service and in probabilistic branching among services that represents different severity levels or different practice patterns.

The HCM uses other categories to represent tracing and immunization and to simulate the consumption of resources used to locate and, if necessary, to vaccinate those who have had contact with newly symptomatic patients. We added the tracing and immunization patient streams and protocols to the HCM to represent smallpox. Our intent in setting up these categories is to estimate the workload of public-health workers and licensed professionals and how it might grow as the epidemic grows.

Results

Public-Health-System Responses

We began our analysis with a generic look across a set of mitigation strategies that included vaccination strategies in isolation and in combination with other strategies. We first conducted experiments to compare a ring-vaccination program in isolation, a mass-vaccination program in isolation, and a combination of ring- and mass-vaccination programs. While tracing and immunizing a victim’s contacts is an effective strategy for naturally occurring diseases, it is not adequate by itself to abort a smallpox epidemic resulting from a bioterrorist attack. We started with 10 initial victims in this series of experiments. With ring vaccination only, an uncontrolled epidemic resulted, with 22,688 smallpox victims seeking medical care in the 180 days following the attack. Mass vaccination alone resulted in 1,291 victims, and the combination of both vaccination programs resulted in just 716 victims.

In the case of a bioterrorist smallpox attack, where the population has little or no initial herd immunity, the disease will spread at an alarming and uncontrolled rate if ring vaccination is the only remediation strategy. Ring vaccination targets susceptible people who have been in contact with an infectious person and may already be infected when vaccinated. In subsequent experiments, we found that ring vaccination combined with isolation or quarantine of infected contacts at the beginning of the prodromal period can be quite successful. For example, a quarantine program with only a 50 percent success rate would reduce the number of victims by 92 percent, with an accompanying dramatic decline in the number of contacts who must be vaccinated and only a modest number of victims who are quarantined. These results are consistent with Porco et al.’s (2004) when the number of individuals initially infected is small; they are also consistent with the successful isolation of infectives that helped curb the severe acute respiratory syndrome (SARS) epidemic in Toronto in 2003 (Patterson 2005).
Similarly, temporary modifications of population behavior that result from public service announcements (PSAs) or education initiatives can also be effective (Figure 1). In a series of experiments, we reduced the numbers of casual contacts per victim per day over a period of days from 10 the first day to eight, six, five, four, three, or two on day 19 and beyond. The only other active mitigation strategy in these experiments was ring vaccination. The number of smallpox victims declined rapidly with a reduction of one or two casual contacts per day and gradually leveled off as the opportunity to transmit the disease was removed.

On the other hand, as previously observed by Kaplan et al. (2002), mass vaccination is successful because susceptible people are generally vaccinated before they are infected, which drastically reduces the probability of transmission if they do come into contact with an infective. We conducted several experiments to determine the performance parameters needed for mass vaccinations to raise herd immunity sufficiently. In these experiments, we varied the number of people vaccinated per day, the percent of the population vaccinated, and the beginning day of mass vaccination. The ambitious plan for mass vaccinations developed by the City of San Antonio calls for 270,000 people to be vaccinated daily started within days of confirming smallpox. The goal is to vaccinate 80 percent of the population of 1.4 million people.

Under the conditions simulated, a point of diminishing returns occurred around a vaccination rate of 40,000 per day, which is a significantly lower rate than called for in the San Antonio plan. While other effects could shift this curve, the implication is that the city could redirect resources to other critical activities and accept a lower rate of vaccination.

We conducted three experiments that differed in the maximum percent of the population vaccinated (Figure 2). The number of victims per day was not affected in the first 42 days or so because, by the time the attack was recognized and diagnosis was confirmed on day 12, the first (initial) generation of infectives had already infected the second. In subsequent days, vaccinating 40 percent of the population resulted in an uncontrolled epidemic, whereas, at 60 percent, the epidemic was broken and the number of daily smallpox victims slowly declined. While these results suggest that 40 percent of the population vaccinated is not sufficient to prevent large numbers of victims, later experiments that combined mitigation strategies (for example, mass vaccination plus reducing the number of casual contacts per day) indicate that 40 percent can be effective when combined with other strategies.

**Acute Health-Care Delivery System**

We used the sensitivity analysis to formulate a scenario in which San Antonio was attacked with an aerosolized version of variola major. We subsequently simulated the attack with both the CPM and the HCM. We assumed that the population had no significant herd immunity and that there were 1,000 initial victims (Figure 3). Members of the San Antonio emergency preparedness community suggested the time line and assumptions.

The first victims sought medical care late on day 11 (that is, 11 days after the attack). As a result, public-health officials recognized the attack on day 12 and issued a community-wide alarm. Public-health workers immediately mobilized to trace and immunize individuals who had come into contact with victims. We had assumed that such an effort would have a 40 percent success rate, but inadequate numbers of public-health workers precluded timely vaccination of most contacts. The city abandoned the tracing-and-immunization effort on day 30 of the crisis because of the backlog. At the same time, it began PSAs,
Figure 2: These epidemic curves show the impact of mass vaccination of varying percents of the population in the absence of any other public-health measures. For the conditions represented here, a 40 percent vaccination rate was inadequate to prevent a runaway epidemic, but a 60 percent rate was sufficient. The multiple peaks in each curve represent the arrival of succeeding generations of victims to the acute-medical-care system. All curves during the first two generations are identical because vaccination cannot begin in time to protect anyone in these early generations of the disease. When the epidemic was controlled, the second generation created the largest surge in demand for medical care.

Figure 3: This time line summarizes the hypothetical smallpox bioterrorist scenario that we used to investigate the ability of the San Antonio preparedness community to address the surge in demand for public-health and acute medical care.
which reduced casual contacts between infective victims and susceptible individuals. The alarm and associated PSAs also caused some victims to seek care during the prodromal period (we assumed 10 percent). We assumed that mass vaccination began on day 17, reached 270,000 individuals per day, and eventually reached 40 percent of the population.

The HCM’s representation of acute care in San Antonio included several aggregates of hospitals and associated numbers of available intensive care unit (ICU) and medical/surgical (M/S) beds (Figure 4). Available M/S beds are those dedicated to the National Disaster Medical System (NDMS); ICU bed counts correspond to 50 percent of the total ICU beds present at each grouping of hospitals. Patients were assumed to enter the acute-care network via one of three routes: (1) the emergency room at one of the hospitals, (2) a physician’s office or clinic, or (3) a community triage center.

HCM’s initial projection of requirements for selected resources at the medical facilities indicated shortfalls in the supply of M/S beds, ICU beds, and nursing hours. We designed subsequent model experiments to investigate ways to alleviate these shortfalls. To relieve the shortfall in M/S beds and to reduce the demand for nursing care, we posited the availability of convalescent beds for the least severely ill patients who required hospitalization. We assumed that convalescent patients could occupy beds that afforded a lower level of care than standard M/S beds, likely in temporary medical facilities in schools, armories, or other public buildings. In the final model excursion, we assumed that 22 to 29 percent (depending on age and vaccination status) of patients between the ages of five and 64 would occupy convalescent beds (Figure 5). We assumed that one nurse was needed for every 20 patients (compared to one for every 10 M/S patients). We thus reduced demand for M/S beds to a level that could be met by the available supply and reduced the demand for nurses too little to resolve the nursing shortage.

To relieve the shortfall in ICU beds and to further reduce the demand for nursing care, we posited the availability of hospice care for terminally ill patients. In the final model excursion, we assumed that physicians would identify 10 percent of those ICU patients who were 15 to 39 years old and would eventually die as terminally ill and would transfer them to hospice care. Similarly, we assumed that they would identify 80 percent of terminally ill patients over 40 as terminal and would transfer them to hospice beds. (We assumed that no children under 15 would be moved to hospice beds.) We assumed that one nurse could care for 10 hospice patients (compared to one nurse for every two ICU patients). We thus reduced the demand for ICU beds to a level that could be met by

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Figure 4: For each aggregate of medical facilities in our representation of the San Antonio acute-medical-care system, we show the number of intensive-care-unit (ICU) beds, medical/surgical (M/S) beds, and mental-health (M/H) beds that would be available in a crisis, as well as patient referral patterns to and from other facility aggregates.

Figure 5: We show the time-phased supply of and demand for medical/surgical (M/S) and convalescent beds in the base case and in the final excursion. Peaks and valleys in the curves reflect the demand of succeeding generations of victims. In the base case, the peak demand for 1,415 M/S beds on day 40 greatly exceeded the supply of 990. In the final excursion, the use of up to 557 convalescent beds by the least severely ill of those patients requiring hospitalization reduced the peak demand for M/S beds to one that could be met by the available supply.
the available supply (Figure 6) and further reduced the demand for nurses. Even with the effect of adding convalescent care, the supply of nurses was still inadequate to resolve the nursing shortage.

Nursing shortages during a surge in the demand for inpatient care might lead to relaxation of usual staffing ratios, with nurses caring for more patients than would normally be deemed acceptable. To investigate the resulting ratios for our hypothesized crisis, we modified nurse to patient ratios until the demand could be met by the supply. In the final model excursion, we assumed one nurse for every three ICU patients (rather than one to two in the base case) and one nurse for every 12 M/S patients (compared to one to 10) (Figure 7).

**Discussion**

Our analysis showed diminishing returns for some strategies to abort an epidemic. Furthermore, experts doubt that the community (San Antonio) could apply a single mitigation strategy well enough to stop a bioterrorist-induced epidemic of smallpox. For example, they doubt that over 40 percent of the population would voluntarily submit to vaccination and do not know if a 20 percent reduction in casual contacts is possible nor what percentage of victims would voluntarily seek care at the onset of high fever knowing that a smallpox epidemic was in progress.

However, by combining the various strategies at less than optimal performance levels, they could abort the epidemic. For example, a community response in which only 40 percent of the population was vaccinated, casual contacts were reduced by only 20 percent, and only 10 percent of victims sought care during the prodromal period could abort a smallpox epidemic. While we did not consider the costs of resource requirements, we believe that pursuing a suite of strategies at a reasonable level of effectiveness and within time and existing resource constraints would form a robust and effective response to an attack.

Our results indicate that ring vaccination alone would likely fail. Ring vaccination combined with isolation or reduction in casual contacts could be quite effective, but the human resources needed might be prohibitive in a large attack. With 1,000 initial cases of smallpox, the San Antonio Metropolitan Health District would experience a large backlog of cases on the second day after the first victims sought medical care. This backlog, coupled with the necessity to vaccinate the contacts of these initial victims within a few days, would make the strategy impractical.

In our combined analysis of the hypothesized smallpox attack, San Antonio’s acute-health-care delivery system could not handle the surge in demand using normal treatment practices. This surge in demand occurred in spite of the public-health system’s assumed aggressive efforts to halt the spread of the disease. These efforts would not reduce the size of
the first and second generations of victims because they would not begin until the first generation of victims began to seek care and the second generation had been infected. Unless officials recognized that an attack had taken place before physicians diagnosed the first patient, the acute-care-delivery system would face a major surge in demand despite the best efforts of the public-health community and public cooperation. Under these circumstances, our results indicate a need for a community-wide coordination of resources, a definitive triage policy, and temporary treatment practices that would allow the best outcomes for the greatest number of people.

The San Antonio community is integrating our results into its planning.

Appendix. Model Structure and Statistical Analysis of Results

The CPM is a discrete-event simulation written in the MedModel environment and uses Microsoft Excel for managing input and output data. It simulates the spread of disease between an infective and susceptibles who reside in the same household or are casual contacts within the community. Casual contacts follow a Poisson process with an input average number of contacts per day that can vary during the simulation (Figure 8). A contact results in transmission of the disease with an input probability that differs for household and casual contacts and depends on the vaccination status of the infective and that of the susceptible. Transmission of the disease creates a new infective who, after an appropriate incubation period, exhibits similar contact and disease-transmission behavior. We represent the effects of public-health measures, such as vaccination, public service announcements, and quarantine, in model inputs describing vaccination rates, contact and transmission rates, and removal of infectives from the population.

The HCM is a discrete-event simulation written in Borland’s Delphi development environment. We use Microsoft Access for managing input and output data and Microsoft Excel for tabular and graphical presentation of summary results. The model simulates the diagnosis and treatment of a stream of patients seeking care in a network (or complex) of acute-care facilities (clinics, community hospitals, medical centers, and so forth). The model interprets input clinical protocols (Figure 9) to determine the resource requirements and outcomes associated with each step in diagnosis and treatment. We did not model triage and clinical decisions assigning scarce resources to patients, but their results (in terms of patient flow among diagnostic and treatment services and patient outcomes and consumption of resources) are subsumed in the probabilities applied to patients. The model tracks patient outcomes and resource utilization, including

![Figure 8: The CPM simulates the activities of a victim from the time of transmission of the agent through the onset of symptoms and the infectious period until either the patient seeks care or is otherwise isolated or until the infectious period ends. During the infectious period, the victim randomly contacts others in the community; household contacts are assessed at the onset of the infectious period. We create a new time line for each contact to whom the agent is transmitted.](image)
the effects of bottlenecks resulting from competing demands for scarce resources. Patient arrival streams follow a nonstationary Poisson process with daily arrival rates inferred from the CPM’s output. Resource utilization levels and hospital lengths of stay are represented with uniform distributions.

In each model experiment, we included 180 days of simulated disease transmission and (for some of the experiments) subsequent treatment of infected patients. We ran 30 replications of each experiment within the CPM and 10 within the HCM to guarantee statistical stability of the results. To reduce variance, we isolated the random number stream for each stochastic process and used the same starting seeds in each experiment. We examined confidence intervals on the numbers of infectives the CPM generated and on resource utilization and patient mortality the HCM generated to ensure that we had an adequate number of replications. A typical 95 percent confidence interval on CPM results is 8,404 to 8,552 total infectives associated with one scenario (Figure 3). (A CPM experiment could represent a situation on the verge of a runaway epidemic, producing a bimodal distribution of the number of infectives that results from the epidemic occurring in some replications and not in others. In such circumstances, confidence intervals on the number of victims will be much larger than reported here, and analysis of the results will require addressing the bimodality. However, we observed no such results in this analysis.) A typical 95 percent confidence interval on HCM results is 9,808 to 10,239 total ICU bed days and 234,793 to 239,357 total inpatient-care nursing hours in the final model excursion (Figures 6 and 7). The same experiment produced a 95 percent confidence interval of 766 to 791 patient deaths. Given these fairly tight confidence limits, we report only mean results here.

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References


Fernando A. Guerra, MD, MPH, Director of Health, San Antonio Metropolitan Health District, 332 West Commerce, San Antonio, Texas 78205-2489, writes: “This letter supports the submission of a paper, “Responding to Bioterrorist Smallpox in San Antonio,” for your special issue of Interfaces. The paper describes research conducted by the Altarum Institute under a grant from the Agency for Healthcare Research and Quality (AHRQ) that employs two simulation models to study a hypothesized bioterrorist smallpox attack in the City of San Antonio, Texas. In my capacity as the Director of Health for the San Antonio Metropolitan Health District, I have advised and consulted with the research team on this project. “Altarum researchers have worked closely over the last two years with multiple local agencies including the Metropolitan Health District, the Greater San Antonio Area Hospital Council, the University of Texas Health Science Center at San Antonio, and emergency responders to capture the details of response plans designed to deal with such disasters. The research investigates a number of potential public health responses to a smallpox attack and then analyzes the impacts that the resultant stream of victims would likely have upon the surge capacity of our hospital infrastructure.

“The research on potential public health responses first isolated the effects of each response parameter and then evaluated combinations of responses. This process was valuable for validating and adjusting our existing plans. For example, the analytical results indicate that our plan to vaccinate the 1.4 million people of San Antonio will succeed in rapidly establishing a sufficient level of immunity to abort an epidemic. Further, their work has demonstrated the importance of an informed and cooperative citizenry in the reduction of disease transmission.

“As with most communities, San Antonio has a limited capacity in its hospital infrastructure to absorb the surge in demand that might result from bioterrorism. The Altarum research team investigated the surge in demand over time and conducted model experiments in search of creative ways to alleviate critical resource shortfalls.

“Altarum has freely shared their work with the planners, leaders, and decision makers of this community and its public health department. Their work has been meaningful and insightful, and has contributed to the readiness posture of San Antonio.”