An Analysis to Determine Whether Quarantine is an Effective Response to a Bioterrorist Attack in the United States

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INTRODUCTION

"*In the life sciences (biotechnology), we are now where information technology was in the 1960's; more than any other science, it will revolutionize the 21st century"*

-- U.S. Central Intelligence Agency Report, 3 November 2003

Throughout history, the threat of biological warfare and naturally occurring epidemics have been a persistent fact of life. There is evidence that the Greeks, as early as 300 B.C., poisoned the wells of their enemies with animal corpses. Although the germ theory was centuries away, military commanders clearly understood how disabling the fear of infectious disease could be when they catapulted diseased corpses over the walls in Tortona, Italy in 1422 (Poupard and Miller, 1992). The record for naturally occurring epidemics is equally long; two of the most notorious examples are the Black Death of the 13th century and the "Spanish flu" epidemic of 1918-19 that killed nearly 40 million worldwide (Lutz, et al., 2003). Today however, geopolitics and infectious disease have merged to create a far more deadly threat for the 21st century. Although the threat of biological warfare has confronted civilization for centuries, the potential to create and/or modify biological agents to artificially induce serious epidemics has now exponentially elevated the risk from hundreds and thousands to tens of thousands and potentially millions. The United States is facing a "superpower paradox" in that its unrivaled military supremacy is prompting its adversaries to seek less conventional methods to attack its civilian population; biological weapons have been described to be the "poor man's neutron bomb" (Atlas, 2002). At the same

time, America's adversaries are increasingly ruthless and openly advocate indiscriminate killing to achieve their goals. Unlike some chemical or nuclear agents, many biological agents are inexpensive and can be commercially acquired, the technology for weaponization is readily available, their incubation periods make it difficult to trace the perpetrator, and large quantities of very destructive agents can be produced in a small area. The Stockholm International Peace Institute estimated the cost to inflict civilian casualties was $2000 per square kilometer with conventional weapons, $800 with nuclear weapons, and $1 with biological weapons (Atlas, 2002). Polgreen and Helms (2001) contend an "array" of biological weapons could be produced with just $10,000 worth of equipment and 250 square feet of lab space. For nation-states with a desire to produce such weapons, it is a seamless and invisible transition from producing commercial vaccines to biological weapons. Yet for all their technical advantages, the greatest danger these agents possess is their ability to instill widespread fear and their potential to uncouple the very fabric of society.

Given the progress of medical science in the 20th century in combating infectious disease, it is easy to forget the ever-present and ominous threat communicable disease posed less than a century ago. Although some diseases such as tuberculosis have been resurging in recent years, improvements in sanitation and hygiene, along with vast improvements in medical therapies have made many diseases commonplace in 1904 unheard of a century later. As a result, the public health infrastructure in the United States, which had routinely and effectively dealt with potential epidemic agents such as smallpox, plague, polio, typhus, tuberculosis, and diarrheal diseases, fell into total disrepair within many state and local governments. Impetus for change from the Federal government has been slow; prior to 1995, most officials in the U.S. government thought the use of biological weapons against civilians was unlikely (Polgreen and Helms, 2001). It has taken events such as the Oklahoma City bombing, the subway sarin attack by Aum Shinrikyo in Tokyo, the World Trade Center disaster, and the anthrax mailings to shake the nation into realizing the increasing threat of a biological attack. It has also forced public health planners to relearn many lessons long discarded, such as how to plan for and respond to an infectious disease epidemic. Many gaps still remain in understanding the factors that make one disease more contagious than another; indeed, even the risk to one individual at any given time is a complex cauldron of variables such as length of exposure, environmental conditions, and population density. Although there is no

consensus as to which diseases pose the greatest threat, the U.S. Centers for Disease Control and Prevention (CDC) lists seven diseases as “Category A” agents. The agents in this category pose the highest risk to national security because of the following: they can be easily disseminated or transmitted person to person; they can cause high mortality with the potential for major public health impact; they could cause public panic and social disruption; and, they require special action for public preparedness. These agents are anthrax, smallpox, plague, botulism, and the hemorrhagic fevers, such as Ebola, Marburg, Lassa, and Junin (Atlas, 2002, Kemp, 2001). While the non-contagious agents on this list (anthrax and botulism) have the capacity to kill thousands, the greater concern to the emergency planner should be the remaining contagious agents which can spread silently through an unsuspecting population and, given the capacity of modern travel, be disseminated nearly nationwide before the first symptoms appear. Several of these agents are rare and would be difficult to culture and disseminate. However, in the case of smallpox and plague, it is known both were studied extensively by the Soviet Union and their capacity to be built as weaponized agents are measured in the hundreds of tons (Kemp, 2001). Others concur, stating anthrax, smallpox, and plague pose the greatest threat as biological weapons if used by a terrorist (Polgreen and Helms, 2001).

Today, with a growing realization that the nation cannot completely prevent a biological release, there is increasing attention from public health officials as to what would be the best way to respond to the threat. Examples are mass vaccination, mass isolation, preventive vaccinations given prior to the release, mass administration of preventive medication such as antibiotics, and quarantine. With the exception of the swine flu vaccination program in the 1970’s, the only experience this country has had with these measures has been with quarantine. The last large scale quarantine in the United States was over 80 years ago (Barbera et al., 2001), although documentation exists that it was used to a lesser degree well into the 1940’s. A cursory reading of the literature reveals numerous definitions for quarantine; true quarantine is the enforced restriction of a group of healthy individuals who may have been potentially exposed to a disease. This differs from isolation which only segregates known sick individuals. In response to the outbreak of severe acute respiratory syndrome (SARS) from March to July 2003, the government of Taiwan imposed a true quarantine consisting of two levels; one for individuals believed to have been exposed in-country and another for individuals coming into the country from SARS-

designated areas (CDC, July 25, 2003). In its review, the CDC stated further studies were needed in understanding the spread of epidemics and considered the imposition of this type of quarantine as an unresolved question. Nonetheless, true quarantine of large state-sized geographic areas have been immediately implemented as a course of action in numerous wargames and federally sponsored exercises such as TOPOFF and Dark Winter (O'Toole and Inglesby, 2003; Inglesby, 2001; Barbera et al., 2001). So a dichotomy exists; quarantine is almost universally considered a viable course of action by medical planners, yet many authorities doubt whether the concept is practical or enforceable. Additionally, there is no universal agreement as to whether quarantine is more effective in slowing epidemic progression than other measures such as preventive vaccination, case isolation, or taking shelter in place. In any case, the imposition of quarantine presents formidable logistic, medical, political, and legal challenges.

The intent of this paper is to re-examine the concept of large scale quarantine in light of 21st century society to determine whether this remains a viable response strategy. The paper will examine some historical precedents along with recent attempts at implementation along with the legal and social implications. In order to determine if quarantine or any other response measures are effective, it is crucial to be able to reasonably simulate how a disease spreads through a population. This can only be done either by studying the progression of previous epidemics or by building a model to simulate the progression of disease. Given that the last large epidemic using quarantine occurred nearly 80 years ago, it may not always be practical to consider the progression of an epidemic that evolved in response to medical practices used in the 1920's. This paper will use a tool developed by a CDC researcher to model a smallpox outbreak and determine, at least as simulated by this model, whether quarantine alone or in combination with another response strategy is an effective response. A secondary goal of this paper is to examine whether this model could be used by local, state, and Federal medical planners that do not have an extensive background in mathematics, statistics, and epidemiology in order to give decision makers a realistic assessment as to whether a particular outbreak posed a significant threat, and if so, what measures could be implemented to minimize its impact.

LITERATURE REVIEW

The gravity and severity of the threat is reflected in the amount of medical literature found discussing the ramifications of a bioterrorist attack. Many journal articles discussing this topic were published in 2000 or later. In order to accurately assess whether or not quarantine is a viable response, one must look at the state of the current environment. This literature review will be broken into four phases:

1) evolution of the threat;
2) description of the major disease threats;
3) epidemics and how they are modeled;
4) more recent examples of quarantine.

There is an abundance of medical literature that describes the nature of the threat for all levels of providers, from first responders to nurses to emergency room physicians to senior level planners at all levels of government. In no way should this literature review be considered exhaustive. In an analysis (Tucker, 1999) of 415 chemical, biological, and nuclear incidents since 1960, the predominant motivation behind these actions between 1975 and 1989 was to protest government policies. This shifted to nationalist objectives, revenge, or retaliation after 1990. Numerous articles can be found directed to first responders and emergency room personnel to aid in the differential diagnosis and initial treatment of patients (Cunha, 2002; Tjaden, 2002). An underlying theme for nearly all papers with a clinical orientation is the emergency room's crucial role both in treating the disease and for infection control. This has been re-emphasized in the numerous papers recently written about SARS (ED Management, 2003; Woodend, 2003). Much of the literature reviewed centers around the seven CDC category A disease threats mentioned earlier. One disease not on the CDC list but frequently mentioned in the literature is influenza, both as naturally occurring or potentially genetically reconstituted strains. Although influenza is a common threat experienced worldwide on an annual basis, its ability to cause significant outbreaks should not be underestimated. While usually transmitted by direct contact, it can also be transmitted by aerosol; remarkably, it takes 27,000 fewer virus molecules to cause equivalent illness when transmitted via the aerosol route (Madjid, 2003). Generally new strains of flu are caused each year due to a genetic "drift", i.e., a subtle change in the genetic code of the virus which is usually similar to viruses to which an

individual has already developed immunity. However, there can be a genetic “shifts”, or very large changes in the virus’ genetic code which can cause worldwide pandemics such as the Spanish Flu pandemic of 1918-19. Genetic sequencing of the 1918 virus is nearly complete; a terrorist with a working knowledge of microbiology could artificially create and release one or more viral genetic shifts which would render a single vaccine useless (Krug, 2003; Lutz et al., 2003) . While a single case of smallpox would immediately set off a nationwide response, an increase in the number of influenza deaths in the middle of winter would not likely cause concern until the number of cases rose exponentially - by that time millions would have been infected (Madjid, 2003).

Another contagious biological threat receiving considerable attention in the literature is pneumonic plague. This should not to be confused with the more common bubonic plague, which is a bacteria transmitted to humans by rats or fleas which subsequently invades the lymph nodes creating large nodules (bulboes). This form is generally considered non-contagious. In very rare but considerably more serious cases, this same infection can reach the lungs - this condition is called pneumonic plague. This can be transmitted to others via respiratory droplets (Reilly, 2002) and can be highly contagious. It can also be produced in an aerosol form and dispersed by a terrorist. Pneumonic plague dispersed in this way is also considered to be very contagious and, if not diagnosed and treated within 24 hours after the onset of symptoms, is almost always fatal within 1 to 5 days after exposure (Reilly, 2002; O’Toole and Inglesby, 2001). The World Health Organization estimated that 50kg of the bacteria that causes pneumonic plague released over a city of 5 million would cause 150,000 cases and 36,000 deaths (Polgreen and Helms, 2001). Although articles on the effects of a plague outbreak were abundant, there were no articles found that described a model for planning a response or the effectiveness of any potential response to a plague epidemic.

In dealing with smallpox specifically the literature reviewed encompasses three areas: articles on the diagnosis and treatment; the ability for the virus to be transmitted; and numerous articles on scattered outbreaks of smallpox before it was officially eradicated. Texts by Christie (1980) along with Roy and Anderson (1991), serves as the foundation for many of the journal articles reviewed, even those recently written. A key difficulty for nearly all researchers is that, since smallpox was naturally eradicated from the planet in 1980, one can only surmise how it travels through a population by using older studies in the

literature. Because modeling disease patterns is so difficult, many authors frequently describe past epidemics in order to shed light on how these diseases travel. Several articles (Pennington, 2003; Meltzer, 2001; CDC, June 28, 1996) provide an excellent description of earlier smallpox epidemics. In some cases, considerable latitude has to be used; the bottom line is that no one can predict with any degree of certainty just how smallpox would travel in a population where more than half were born after routine vaccination ended in 1972.

The threat of biological agents being released into the general population has also brought a renewed interest in the study of epidemics. Numerous articles in the literature describe the possibility of previously eradicated diseases being re-introduced into society; besides the three mentioned earlier, one can readily find discussions related to botulism, tularemia and brucellosis (Tjaden, 2002). Because of its natural predilection and its previous history earlier in the 20th century, studies on influenza are abundant. One author (Fleming, 1994) took 25 years of occurrence data to develop an algorithm to apply to weekly occurrence data in order to predict when an epidemic would occur. As mentioned previously, researchers can take past occurrence data and try to extrapolate what could happen in the future; others prefer to construct models. While there are very few models available for commercial use, several authors were found to have developed proprietary models for their own purposes. Flahault (1994), using data on influenza originating from a 1984 study of French rail passengers, developed a complex model for passengers traveling by air across a network of 9 European cities. His results showed a very short lag between travel of the original cohort and the development of influenza in all 9 cities. Other studies developed different styles of modeling to better identify disease trends using basic medical surveillance data (Le Strat and Carrat, 1999), some compared different diseases such as measles (Cliff, 1993), and others analyzed epidemic progression in very isolated populations, such as an influenza epidemic in the Canadian Sub-arctic (Sattenspiel, 1998). Models using data obtained from the 2003 SARS outbreak can be found in the literature as well. Lipsitch and his colleagues (2003) used data from the outbreak in Singapore and elsewhere to model future outbreaks and Nishiura, et al. (2004) used modeling techniques to attempt to explain why the SARS epidemic did not strike Japan as seriously as other Asian nations. This paper concluded, with respect to SARS, that the eventual size of an epidemic could be roughly estimated from the size of the initial attack. It also concluded public health interventions such as

quarantine and other precautionary measures impacted the transmissibility of the virus (Nishiura, et. al., 2004). One study (Legrand, et al., 2003) developed a model to examine the impact of different variables in a smallpox release when responding with case isolation and ring vaccination. This study found early recognition of the epidemic as a key component to a successful response.

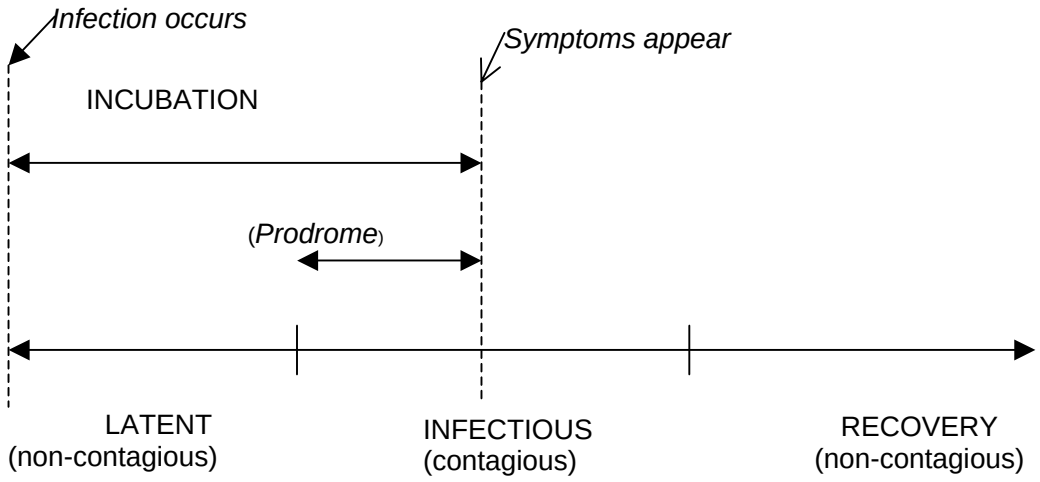
Most of the models used in these papers require a very extensive knowledge of advanced mathematics, statistics, in addition to epidemiology which is far beyond the reach of the average medical planner. A CDC colleague of Dr. Martin Meltzer, who developed the model used in this study, noted in an email communication to the author (Dr. John Glasser, September 17, 2003) that his simplest model was a compilation of 17 differential equations. What was surprising was the paucity of epidemic modeling tools available outside academic circles. No models of any kind were found to be commercially available; nearly all the models described in the literature are embedded within academia and unavailable. Although Dr. Meltzer's model makes some broad assumptions, it has the advantage of working on an Excel spreadsheet using only 4MB of space. Medical planners at the local, state, and Federal level need a straightforward method to model a given disease in order to assess and validate various courses of action.

Lastly, although there are a number of papers in the literature that describe the threat of bioterrorism, there are fewer that discuss the ramifications of possible responses. One notable exception was several papers describing the legal implications of quarantine found in medical legal journals. The medical literature reviewed showed no references to large scale quarantine occurring within the United States after the 1920's. Smaller degrees of quarantine did occur; one example was a smallpox quarantine imposed in central Pennsylvania in 1942-43 discussed elsewhere in this paper. So forgotten was this episode that the Pennsylvania Department of Health could not confirm the location of the outbreak – only the numbers infected at the time (Mr. James Rankin, October 7, 2003). Nearly all recent papers that discuss quarantine do so in connection with SARS. One can presume further studies on the lessons learned about the quarantine experience in Taiwan, mainland China, and Canada will be published over the next few years; however, some of the methods used by the Communist Chinese government to enforce their quarantine, specifically the death penalty, obviously does not translate into western societies (Mitka, 2003).

METHOD AND RESULTS

This paper will use a tool developed by a CDC researcher to model a smallpox outbreak and determine (at least as simulated by this model) whether quarantine alone, or in combination with another response strategy, can be considered an effective response to a smallpox epidemic. The model, developed by Dr. Martin I. Meltzer and his team at the CDC and provided by Dr. Meltzer to the author, has been described in detail in the literature (Meltzer, 2001). The model, hereafter referred to as the "Meltzer model", uses a Markov chain concept to describe the spread of smallpox through a population and resides on a Microsoft Excel spreadsheet (Excel97, Microsoft Corporation, Redmond, WA). In order to understand the strengths and limitations of the model, it is necessary to understand the disease process of smallpox in general.

Broadly speaking, the disease process consists of three phases. First there is the latent period, where the individual is infected but not contagious. Next there is the infectious period where the individual is both infected and contagious. The very beginning of the infectious period is the "prodrome", i.e., where the patient is contagious but does not show signs of the disease. At some point during the infectious period (different for each disease) the patient exhibits recognizable symptoms of the disease. The last phase is the recovery period where the individual either recovers from the infection or dies. This phase begins when the patient is no longer contagious. One other period, the incubation period, is defined as the period of time from the initial infection to observable signs and symptoms (Anderson and May 1991). This is graphically represented below:



A unique characteristic of smallpox is that, compared to other diseases, its 12 to 14 day incubation period is unusually long. If vaccination can be implemented within 2 or 3 days after exposure there is almost 100% protection and even vaccinating as much as five days post exposure can protect against death (Henderson, 1999; Christie 1980). Legrand et al. (2003) concurs, concluding the time needed intervene was a key parameter for effective control of a smallpox attack. *For the emergency planner, the ability to rapidly institute a smallpox vaccination program upon definitive confirmation of a smallpox outbreak can save many lives.*

There are several key parameters to account for when using the Meltzer model. These are the incubation period, average duration of the disease, degree of contagiousness, and the interventions (such as quarantine and vaccination) used to control the epidemic. The incubation period and average duration of the disease are fully outlined in the unedited version of this paper. Another component of the Meltzer model is its ability to quantify how contagious the disease is, that is, just how many people one infected person can pass their disease to. There remains, even within the scientific literature, considerable controversy as to just how contagious smallpox would be in today's mostly unvaccinated population. Some authors (O'Toole and Inglesby, 2003; O'Toole, 1999) describe exercise simulations and scenarios of a single bioterrorist release of smallpox causing an epidemic over several states; in one scenario there were over 15,000 infected with more than 2,000 deaths in 60 days. Others refute this, stating smallpox is not as transmissible as measles, chickenpox, or influenza (Bremen and Henderson, 2002; Mack 2003).

Pennington (2003) agrees, quoting a 1972 study saying "under contemporary conditions smallpox cannot be said to live up to its reputation. Far from being a quick footed menace, it has appeared as a plodding nuisance with more bark than bite." Although principal spread is by droplets from the respiratory system, the virus does shed in the early stages of the rash which can infect clothing or bedding. Mack (2003) suggests the virus only travels within saliva droplets which are too large to be carried over long distances and believes the greatest concern should be the possibility of transmission within hospitals and among direct caregivers. He references a study that found over 60% of smallpox cases in post-war Europe came from hospital patients, workers, and visitors and that the last three outbreaks in the United States (Seattle, New York, and the Rio Grande valley) were all directly traceable to hospitals. Kemp (2001) concurs, advising hospital laundry and mortuary personnel should be considered at high risk and recommends all persons suspected of having smallpox be isolated in their homes and not in a hospital. He further recommends a single hospital be designated for seriously ill smallpox patients in the event of an epidemic. Other authors agree (Hull, et al., 2003; Meltzer 2001, Appendix 1; Neff, 1971) that close contact is required to transmit smallpox and it was not readily spread by brief and casual encounters. Nonetheless, while close contacts have the greatest potential for contracting the disease, there is ample evidence showing the virus has an uncanny ability to spread in unexpected ways. In then-West Germany, a single patient in isolation on the hospital's ground floor spread the disease through the ventilation system to 16 other patients throughout the three story facility and to one visitor who went no further than the entryway for just 15 minutes (Gelfand and Posch, 1971). Others describe a messenger who stopped in the laboratory of an Army hospital for a cup of coffee and contracted the disease 15 days later (Dworetsky, 2002), or a case contracted after visiting an infected friend at home for only a few minutes (Pennington, 2003). As Christie (1980) writes, "no one with any experience of the disease doubts its ability to smolder through the undergrowth and burst into flame in unexpected places, just when it is thought to be fully under control."

The last variable in using the Meltzer model are the interventions used to control the epidemic, i.e., quarantine and vaccination and a determination as to the number of days necessary to implement these interventions. One scenario (O'Toole, 1999) began large scale vaccination 17 days after the initial exposure which included two days to confirm the diagnosis. In his model Meltzer (2001) postulates any

large scale intervention will not begin until day 25, although that does not preclude an earlier, more local response. He bases his calculation on 15 days from exposure to overt symptoms, 2 days for initial clinical diagnosis, 1 day for specimen transport, 3 days for laboratory confirmation, and 4 days to mobilize for a large-scale intervention. While there is a significant discrepancy between the O'Toole and Meltzer time frames, one should consider leaning toward the latter because of the inevitable confusion that would be involved in making the initial diagnosis. Henderson (1999) states "because of the wide variation in how the disease manifests, it (smallpox) can mimic other diseases in the early stages such as measles and chickenpox". Pennington (2003) cites a 1953 smallpox outbreak in Todmorden, England, where numerous cases were either incorrectly diagnosed (either chickenpox or pneumonia) and several other cases that were only diagnosed retroactively when patients either recovered or post-mortem. He notes this was a classic example of how a deliberate release would occur today. The outbreak was in a non-endemic region (and thus unexpected) where the source of the virus was never established. In spite of the fact smallpox was not yet eradicated at the time, many physicians still missed the diagnosis. Even with improvements in preparing physicians for potential bioterrorist events, it has to be considered highly probable the first cases of smallpox will initially be diagnosed as something else. In the Meltzer model, quarantine is not applied to a geographic region but rather by quarantining a specific percentage of the population that show overt symptoms on a daily basis over a specific period of time. Note that Meltzer's model does not take into account those who might be quarantined along with the infectious persons, such as unvaccinated household contacts and other exposed persons (Meltzer, 2001). Vaccination is indirectly applied by proportionately reducing the transmission rate since vaccination makes these individuals no longer susceptible.

Although somewhat beyond the scope of this paper it bears mention that while it has been clearly demonstrated vaccinating exposed individuals may prevent an individual from contracting the disease, the vaccination itself is not without risk. In each year prior to terminating universal vaccination, there were between 5 to 10 deaths, over 200 hospitalized, and hundreds of significant complications from the vaccine (Neff, 1971). Nor does vaccination provide lifetime protection; estimates for immunity from a single immunization ranges from 10 years to 25 or more - - no one really knows for certain (Christie, 1980; Neff, 1971). Extrapolating previous data, one author contends a mass vaccination program for a

population of 250,000 would kill several and the media hysteria surrounding the vaccine's complications will accelerate noncompliance even in an outbreak (Mack, 2003). Past history seems to confirm this; in a 1962 smallpox outbreak in the United Kingdom, 21 died from smallpox and 17 died from the effects of vaccination (Pennington, 2003; Christie, 1980).

The Meltzer model allows medical planners to rapidly change the factors listed above to ascertain the best possible response. This paper examined ten scenarios using various transmission rates and quarantine durations. The most favorable case is using a transmission rate consistent with the view that smallpox is most contagious to close contacts and a 10 day quarantine to allow implementation for mass vaccination program. In this scenario, the model shows the epidemic can be contained within 60 days with no new cases appearing after 120 days.

ANALYSIS AND DISCUSSION

It is unknown when the practice of isolating sick individuals was first practiced, although the Bible mentions separation of lepers. The term quarantine is derived from both the Latin "quadragina" and the Italian "quarante" which referred to the 40-day sequestration of merchant vessels arriving in Venice during plague outbreaks in the 14th century (Cummings, 1921). Although defined by the Oxford English Dictionary (1989) as a "period of isolation imposed on a person, animal, or thing that might otherwise spread a contagious disease", the term is broadly used today to describe any number of containment measures from travel restrictions, restrictions on public gatherings, or isolation of sick individuals (Barbera, et al., 2001). The CDC makes the following distinction: isolation is the separation of *already ill persons* with a contagious disease, usually applied at an individual level. Quarantine is the restriction of movement of *healthy persons presumed* to be exposed. This could be applied at an individual or community level and may be voluntary or mandatory (Simone, 2002). Both of these actions have numerous legal and social implications and Barbera, et al. (2001) stresses the need for medical and public health emergency managers to use the correct terminology.

Many of the difficulties with quarantine can be directly traced back to its history. Beginning with colonial times and continuing over the next two centuries, state governments were given very broad authority to protect public health, usually referred to as a state's "police power" (Annas, 2002).

Massachusetts established quarantine powers in a comprehensive public health statute in 1797 (Barbera et al., 2001). The U.S. Supreme Court, in the 1824 case of Gibbons v. Ogden, opined that "inspection laws, quarantine laws, (and) health laws of every description" were essential regulatory powers of the state (Parmet, 1989). In 1905, the court in Jacobsen v. Massachusetts upheld the power of the state to require vaccination, and the Maine Supreme Court ruled in 1874, "when the smallpox or any other contagious disease exists . . .the law demands the utmost vigilance to prevent its spread . . .*salus populi suprema lex*, the safety of the people is the supreme law" (Parmet, 1989). However, at about the same time the states were beginning to exercise their authority, the Federal government also passed laws (1796) authorizing the president to assist in state imposed quarantines. In 1878, responding to a number of yellow fever epidemics, Congress passed the Federal Quarantine Act which directed the Surgeon General of the Marine Hospital Service (the forerunner of the U.S. Public Health Service) to draft rules and regulations governing the quarantine of vessels from foreign ports and directed consular officers overseas to keep the Surgeon General informed on the sanitary conditions of the ports in their countries. Nonetheless a vigorous debate ensued between the states, who believed public health was a state matter, and the Federal government which believed it had ultimate jurisdiction as the imposition of quarantine often impacted interstate commerce. Congress, responding to an imported cholera epidemic in 1892, expanded the interpretation of the 1878 law giving the Federal government greater authority in imposing quarantine. Finally, in 1944, the Public Health Service Act gave the Federal government ultimate jurisdiction when there was a conflict between state and federal activities, although the states still retained the right to impose quarantine within its borders. For all the legal activity, however, Federal imposition of quarantine has been rare. The last Federal use of quarantine was during the Spanish Flu outbreak of 1918-19 (Mitka, 2003; Barbera et al., 2001; Cummings, 1921).

Because of the sovereignty given to the states to protect public health in the early 20th century, there were very few cases where the individual whose liberty was restricted challenged the rule of the state (Parmet, 1989). In many cases, states and local governments often enacted quarantines in response to ignorance and bias rather than containing a disease. Throughout the Middle Ages, Jews were often blamed for spreading bubonic plague and in 1892, Jewish immigrants from Europe were quarantined on their ships when cholera was detected in a group of earlier arriving immigrants.

Passengers of lower socioeconomic status were forced to remain in their quarters below deck without sanitary provisions. Cholera disproportionately spread throughout the lower decks, killing 58 on one ship alone. Quarantine was instituted around a Chinese neighborhood in San Francisco in 1900 after several inhabitants were diagnosed with plague. The quarantine was arbitrarily established only around Chinese households and businesses causing severe economic damage to the community (Mitka, 2003; Barbera et al., 2001). In 1893 an outbreak of smallpox struck the city of Muncie, Indiana. Because of disagreement within the medical community that the disease was truly smallpox, there was a marked lack of community support for the quarantine measures, such as the elimination of public gatherings within the city (to include school and church services), the restriction of individuals wishing to enter the city on business, and mandatory vaccination. Police were stationed outside the homes of those afflicted. Violence broke out and several public health officials were shot. Fear spread well beyond the city as well; an adjacent county ruled anyone entering the county from Muncie would be forcibly quarantined for 10 days whether they could demonstrate they had been immunized or not (Eidson, 1990). This past history explains the reluctance of public health officials to propose quarantine and inevitable questions that arise when it is implemented; one only needs to recall the clamor when the suggestion surfaced to quarantine AIDS patients and the resurrection of cultural stereotypes about Asian communities being unclean during the recent SARS outbreak (Parmet, 1989).

Since the states have retained much of their traditional role in enforcing public health policy there remains a diffuse and variable patchwork of 50 disparate policies nationwide. According to Gostin and his colleagues (2002), most state statutes have evolved over so many years that the rules may even vary within the same state depending on the disease in question. In response to the myriad of public health laws across the country, Georgetown and Johns Hopkins University developed a model state emergency health powers act (Gostin, et al., 2002) which combines the missions of preparedness, surveillance, management of property, protection, and communication into a draft law the states may use as a template when revising their own public health statues. In the model act, upon the declaration by the governor of a public health emergency (either naturally occurring or induced), the state may implement “special powers” which include confiscation of property, forced examination, vaccination, isolation or quarantine of individuals, and the waiver of licensing requirements in order to direct health care

professionals to examine or treat patients (Gostin, et al., 2002). Although the model act has served as a template for the revision of public health legislation in 34 states, there is marked concern about the model's impact upon civil liberties if the model were adopted as law outright. Annas (2002), in his article opposing the model law, states "provisions that treat citizens as the enemy, with the use of police for enforcement, are much more likely to cost lives than to save them." Although the model act has been revised (Annas, 2002), concerns regarding civil liberties still exist.

The concerns the model act raise reflect a marked shift in how the public perceives illness and the public interest. Where few once questioned the power of the state, the decline of communicable diseases, the rise of the medical profession, and the development of an individualistic, rights-based jurisprudence have created a vision where the individual is given considerable latitude in making their own choices in how their disease will be treated, even when it is contagious (Parmet, 1989). This is true even in situations where the state continues to have a strong public health interest, such as tuberculosis (TB) and AIDS. The courts, while rarely challenging the state's authority to enact and enforce public health laws, generally have insisted the state exercise every recourse to protect an individual's civil liberty. A West Virginia court found in 1980 that the state violated an individual's right to due process when it involuntarily confined a man with TB but did not advise him of his right to counsel, even though this provision was not expressly written into the state statute. A 2002 decision found the state of California in violation of its quarantine law when it placed a Laotian woman with multi-drug resistant TB in jail for failing to appear for a medical examination. The court struck down the action because the quarantine order was only written in English even though the woman did not speak English and because the state incarcerated the woman in jail. This was in direct opposition to California law which mandated the state could only involuntarily quarantine persons in hospitals or other medical treatment facilities (Lacey, 2003). The problem remains that while Federal law takes precedence over state law when the two are in conflict, in most situations the myriad of 50 state public health laws remains the only law available. There are no contemporary U.S. Supreme Court cases interpreting state quarantine authority; nor has the question been resolved as to the Federal role should a state's enforcement of its public health laws impact another state or the rest of the country. For example, no hospitals have consented to be quarantine facilities in Washington State (Lacey, 2003).

The recent SARS epidemic has brought the concept of quarantine back to the forefront. The CDC outlined measures taken by the government of Taiwan during the spring 2003 outbreak. Taiwan imposed two types of quarantine; a level A quarantine for those who had been in close contact with a SARS patient, and a level B quarantine for those coming into Taiwan by air from SARS affected countries. For level A, close contact was defined as health care workers, family members, co-workers physically working close to the affected person, classmates who had spent at least one hour with the patient, passengers and drivers of buses or trains where contact had been 1 hour or more, and those who sat in the same or the adjacent three rows from a SARS patient on an airplane flight. Persons were asked for 10 days to remain either in place (either at home or, in the case of health care workers, within the hospital), take their temperature 2 or 3 times daily, and seek medical attention promptly if they developed fever, shortness of breath, or other respiratory symptoms. Persons under level A quarantine could only leave their area for activities deemed necessary by local health authorities; meals were provided and delivered daily. Persons under level B quarantine could choose to remain for 10 days in an airport hotel, at home, or at quarantine centers located on military bases. Persons under level B quarantine could leave the area to seek medical attention, exercise, purchase meals, and conduct other business as approved by local health authorities. All outdoor trips were documented to facilitate possible future investigations. The Taiwanese government also installed video monitoring equipment, originally intended for quarantine violators, for many quarantined at home and those with enforced movement restrictions at government quarantine sites. In all cases the government provided meals, psychological counseling, and care for other family members to include day care. Individuals were provided other social services from local sources upon request. At the end of their quarantine, individuals were paid $147. Failure to comply with the regulations resulted in fines anywhere from $1765 to $8824 and incarceration up to 2 years. In all, 50,319 were placed into level A quarantine and 80,813 were placed into level B; only 286 (0.22%) were fined for quarantine violations (CDC, July 25, 2003). Such measures were not limited to Taiwan; the government of Singapore also used thermal scanners, web cameras, and electronic bracelets to enforce its quarantine (Gostin, et al., 2003).

The government of mainland China also imposed a SARS quarantine and although details are fewer the literature available implies a lesser degree of success. Zhao (2003) credits rapid case

identification and quarantine with containing the infection in the province where the disease originated, but gives no details on how the quarantine was implemented. Other sources (Mitka, 2003) report more than 10,000 were quarantined in mainland China although it was not universally accepted. When Hong Kong officials went to an apartment building to place its residents under quarantine, they found many had left the area even though the Chinese government had imposed a minimum 10 year sentence with a maximum penalty of life (and possibly the death penalty) for the not complying with the quarantine regulation. What may have made the Taiwanese experience successful was the government's willingness to provide needed social, logistic, and economic support to those impacted by the quarantine. A smallpox epidemic in the state of Pennsylvania clearly demonstrates the economic impact of an epidemic in a local community. In late 1942, smallpox broke out among an unvaccinated Amish population in the Kishacoquillas Valley near Lewistown, Pennsylvania. The source of the infection was from individuals returning home after traveling to Ohio for a wedding. The State Department of Health immediately imposed a quarantine on the 8000 persons living in the region with the Pennsylvania State Police sealing off all roads (Lewistown Sentinel, December 24, 1942). From December 23, 1942 until the quarantine was lifted on January 13, 1943, a total of 41 individuals contracted the disease but there were no fatalities. A review of news articles during this period extensively describes the significant negative economic impact of the quarantine on the region's milk producers and produce vendors who were not able to export their products to local markets and dairies as well as to local merchants who could not receive deliveries. Others impacted were workers in the area who could not leave the area to go to work until they could prove they had been vaccinated. In addition, farm workers in the area could not return to work until they could provide a certificate of health (Lewistown Sentinel, December 28, 29, 30, 1942). Another study (Barbera et al., 2001) considers the current economic risk to be greater today and would extend well beyond the quarantined area as many businesses rely on just-in-time supply chains. He warns that planners should prepare for shortages of food, fuel, medicine, and medical supplies.

One cannot say with certainty that what was successful in Taiwan could be exported to other societies like the United States. In a briefing posted on the CDC website (CDC, 25 June 2002), Dr. Patricia Simone of the National Center for Infectious Diseases proposes principles for a "modern quarantine". These are:

- short term, voluntary home curfew
- suspension or restrictions on group assembly
- cancellation of public events
- closure of mass transit systems
- closing of public places
- restriction of travel
- “snow days” or shelter-in-place
- “Cordon sanitaire” , i.e. sanitary barrier erected around an area

She advocates quarantine to be used in conjunction with other interventions such as enhanced surveillance, rapid accessibility to treatment for everyone who becomes ill, and preventive actions such as vaccination or preventive antibiotics. A key component of her approach is that quarantined individuals must be among the *first* to receive all interventions and it should only last as long as necessary to ensure quarantined persons do not become ill. Gostin and his colleagues (2003) propose four criteria to assess the legal and ethical justification for quarantine. Imposition of quarantine should be justified by the risk the disease poses to society; providing the opportunity for medical testing to rule out if an individual is infected or has been simply exposed to the disease (where available, in the case of SARS no such test exists); a safe and habitable environment for those upon whom quarantine has been imposed; assumption by the government of some of the individual financial burden quarantine imposes; and, the opportunity for those who believe they have been unfairly quarantined the right of due process to appeal such a measure in a reasonable period of time.

There is other evidence that quarantine may not the most effective method of addressing a smallpox epidemic. As mentioned earlier, those at highest risk of contracting the disease were those in close contact as opposed to having just incidental contact. Eichner (2003) maintains case isolation and contact tracing are just as successful in controlling the spread of smallpox. This means that identified cases are immediately isolated and all household members and other close contacts are traced, vaccinated, and put under continuous surveillance for three weeks. Surveillance comprises regular examination of the contacts and taking their temperature twice daily in order to detect any infection at the earliest possible time. Should a contact individual be deemed infected, they are immediately isolated and

their contacts will be isolated in the same manner. Eichner uses a computer simulation that shows, even with a high transmission rate, that using tracing and isolation of this type will control an epidemic in six months with no more than 550 contracting the disease from a baseline of 100 infected. Others simply say quarantine does not work as it is nearly impossible to convince perfectly healthy people to stay put. There's always going to be people who will find a way around it (Mandavilli, 2003).

So should an emergency planner consider quarantine as an effective response to a bioterrorist release of smallpox? The literature strongly suggests smallpox is not nearly as contagious as other diseases, such as influenza. Using the Meltzer model, it can be shown smallpox could theoretically be contained with quarantine only, although the time it would take (from 8 weeks to almost six months) and the high numbers quarantined (25% to 50% of the daily number that show symptoms) makes it unlikely it could ever be fully enforced. Indeed, the data infers the longer the quarantine, the less likely it is to remain intact. However, the data suggests that quarantine, when combined with other response modalities, could be an effective adjunct to contain a smallpox epidemic. If public health officials determine the risk for mass vaccination is justified, the model shows using a limited, 10-day quarantine of at least half the population that show symptoms while a mass vaccination program is prepared could contain the epidemic within 60 days and completely terminate it after 120 days. Further research will be necessary to determine if quarantine is more or less effective than case isolation and contact tracing. Although not explicitly stated by Meltzer, one could surmise using a "modern quarantine" as mentioned earlier in a limited geographic area such as a city would be as effective (or perhaps even more so) than a statewide "blockade" as envisioned by some authors or even what was used in Pennsylvania in 1942-43. This concept of quarantine may also be effective in that it enables public health officials to "do something" in order to modulate what would likely receive widespread and nearly constant media focus, particularly as pictures of the victims became public. *The key parameters for any quarantine are that it should be of relatively short duration, it must be supported by the public as necessary to contain the epidemic, and information regarding the status of the epidemic should be accurate and made available to the public as soon as possible.* Planners should note the success of the Taiwan SARS effort and be prepared to provide immediate and unlimited medical, social, and daily logistical assistance to those quarantined for the duration of their restriction. Government must accept the responsibility, if depriving its citizens of their

liberty even for a short time, to assist individuals in acquiring support that they cannot provide for themselves. If, as a minority suggest, smallpox is highly contagious even beyond close contacts, the model is much less reliable as a predictor of how the epidemic would behave. The Meltzer model described in this paper is designed to be used only with smallpox. Further research is necessary to determine how other contagious diseases that could potentially be used by a terrorist, such as a modified influenza or plague, would spread through a population.

Nonetheless, the Meltzer model is a good first step in providing a scientifically based and easy to use model for emergency medical planners in the case of smallpox. Reliable and straightforward models are needed for other diseases as well to simulate their spread through a given population. While the attention this concern has received in academia is laudable, it is imperative to translate this knowledge into working tools that can be used by emergency planners at all levels of government. Without the ability to evaluate the impact actions such as quarantine, mass vaccination, isolation, or contact tracing, the citizens of this country will be unable to make the choices necessary to effectively respond to a bioterrorist attack.

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