Epidemics of panic during a bioterrorist attack – A mathematical model

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ARTICLE INFO	SUMMARY
	A bioterrorist attacks usually cause epidemics of panic in a targeted population. We have presented epidemiologic aspect of this phenomenon as a three-component model – host, information on an attack and social network. We have proposed a mathematical model of panic and counter-measures as the function of time in a population exposed to a bioterrorist attack. The model comprises ordinary differential equations and graphically presented combinations of the equations parameters. Clinically, we have presented a model through a sequence of psychic conditions and disorders initiated by an act of bioterrorism. This model might be helpful for an attacked community to timely and properly apply counter-measures and to minimize human mental suffering during a bioterrorist attack. © 2009 Elsevier Ltd. All rights reserved.

Introduction

Bioterrorism as an emerging mode of terror comprise a new field of epidemiology that demands ongoing activities at all levels of prevention. The ostensible purpose of biological weapons is to endanger lives. Biological agents, however, are particularly ineffective as military weapons. This may be why armies have generally acquiesced in international treaties to contain these unpredictable weapons and feel capable of waging war without them. Instead, biological weapons are quintessentially weapons of terror. The purpose of these weapons is to wreak destruction via psychological means by inducing panic in everyday life [1].

A large-scale panic may be expected if biological weapons are ever effectively deployed or thought to be deployed [2]. Panic represents the basic fear reaction triggered in situations of danger and is associated with the fight-or-flight response, but the perception of risk is not always in tune with the actual risk [3]. This psychological dimension is difficult to quantify, different in each concrete situation, and often disproportionate to the demographic burden [4].

A number of examples from the near past showed an extent and amplitude of short-term and long-term mental consequences of bioterrorist acts. Between 25% and 50% of survivors, directly exposed to a bioterrorist attack, could be expected to develop PTSD (Post Traumatic Stress Disorder). Moreover, most of those survivors who do not develop a diagnosable psychiatric illness suffer from painful, severe, and often long-term reactions. Fear of biological attacks may be associated with epidemics of medically unexplained illness (also known as mass sociogenic illness, mass psychogenic illness, or mass hysteria), involving the rapid spread of medically unexplained signs and symptoms, which are misinterpreted by affected persons as signs of serious physical illness. Social problems may emerge after exposure to biological agent (e.g., population displacement; breakdown of community support systems; and social stigma associated with contagion or contamination). Persons with altered behaviors may be so numerous that they overwhelm available medical resources [5].

Little appears to be known about how best to handle the panic generated by epidemics during bioterrorist attacks. The aim of this paper is to propose a mathematical model for explanation of epidemics of panic during bioterrorist attacks, its prevention and antiepidemic actions. To our knowledge this is a pioneering attempt in research.

Mathematical model

The purpose of models is to simplify reality and make it easier for the mind to grasp the essence of the issue. Each model has its strengths and limitations on helping to clarify causal thinking. Each model is, however, a simplification [6].

This is our attempt to present a new epidemiological model of panic during and after bioterrorist attack, based on the Lotka–Volterra population model [7]. First, we defined the parameters of a model and their mutual interactions. Using these parameters we formulated mathematical functions of panic and protection against panic. Finally, we formulated model of panic and presented it as a system of ordinary differential equations. The system was solved numerically [8] and graphical presentations of changing panic

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and protection against panic depending on time are given. Considering the epidemiologic aspect of this model the corresponding elements to classic triangle (agent, environment and host), would be information, environmental and social network and host.

Mathematical model presents the intensity of panic (S) and protection and prevention (P) as functions of time.

$$S'(t) = \left[\alpha \left(1 - \frac{S(t)}{C} \right) - \beta P(t) \right] S(t)$$

$$P'(t) = (-\gamma + \delta S(t)) P(t)$$

The first equation defines that panic $S(t)$ increases by the rate α. Panic will obsess the whole population C in the case of absence of the protection $P(t)$. Protection decreases panic by the rate β. The intensity of protection is adjusted by the second equation. It is decreased by the rate γ, but it also depends on panic that increases protection by the rate δ. All four parameters are nonnegative numbers.

Parameter α determines how fast panic spreads. It is a resultant of subjective perception, and global and local environmental influence, e.g., social networks. Greater α means that panic increases faster and it attacks greater population. Panic starts to decrease when protection reaches necessary level. When panic decreases, protection also starts to decrease, but with a delay. If protection is not high enough or if it not last longs enough, panic expands again but with a smaller intensity.

Parameter β represents effects of the protection against panic increase; greater β means that protection is more efficient, so that panic increases slower and panic maximum value is smaller. This parameter reflects the quality of protection. Protection can be adequate if it is efficient, even if it is not very large.

Parameter δ adjusts protection according to panic. Protection is more increased when panic increases for higher values of this parameter. This provokes faster decrease of panic. This factor matches the intensity of protection according to the level of panic.

Parameter γ expresses the rate of decrease of the protection. If it is small a high level of protection will last for longer time. For $\gamma = 0$ protection is permanently on the highest level, panic disappears and does not appear again.

In Fig. 1, five hypothesized combinations of the parameters during a bioterrorist attack are graphically presented through change of panic and protection as a function of time.

Case 1 shows how panic (full line) and protection (dashed line) change in time if parameters are chosen as follows: $\alpha = 4$, $\beta = 3.8$, $\gamma = 1$, $\delta = 1$.

In Case 2 oscillations of panic and protection become smaller in time and the system tends to a stationary state. However, panic is always present in a small extent, and a low level of protection is kept.

In Case 3 graphs are plotted for $\alpha = 6$, $\beta = 2.8$, $\gamma = 0$, $\delta = 1$. Although panic is high, protection does not decrease and it suppresses panic for a certain period. However, keeping protection on a high level permanently is rather expensive and probably not rational.

For higher values of δ, the maximum panic level is lower and the efficiency of protection is better as protection stronger depends on panic (Case 4).

The graphs in Case 5 are calculated using the same values of parameters as the graphs in Case 4, but for a longer period.

When time tends to infinity the system tends to a stationary state that depends on the parameter values (Cases 2 and 5).

$$S'(t) = 0, \quad \left[\alpha \left(1 - \frac{S(t)}{C} \right) - \beta P(t) \right] = 0 \rightarrow \quad P(t) = \frac{\alpha}{\beta} \left(1 - \frac{1}{C} \frac{\gamma}{\delta} \right),$$

$$\beta, \quad \delta \neq 0$$

$$P'(t) = 0, \quad -\gamma + \delta S(t) = 0 \rightarrow \quad S(t) = \frac{\gamma}{\delta}$$

If β is equal to zero protection has no influence on panic. If δ is equal to zero protection does not depend on panic. Panic tends to encompass the whole population C in both cases.

Discussion

Experiences with panic during bioterrorist attacks and hoaxes

If we carefully consider recent experiences from biological attacks, two types of epidemic specific to biological attack can be recognized: the epidemic of infectious disease and the epidemic of fear and panic. The US anthrax bioterrorism attack in 2001, when letters containing *Bacillus anthracis* were sent within the country, showed a real dimension of an epidemic of fear and panic. In total, 22 persons were diagnosed with *Bacillus anthrax* infection of whom five died, over 32,000 people were treated with antibiotics and a tremendous epidemic of panic and fear overwhelmed the whole population. In the aftermath, a large number of letters, approximately 12,000, with suspicious contents were discovered in the USA, as well as 7622 harmless letters across Europe, as imitations of a real attack. They amplified and expanded epidemic of panic and fear, giving it characteristics of pandemic [9].

Over 1000 students in several schools in Manila, Philippines, deluged local clinics with mundane flu-like symptoms such as cough, cold, and mild fever after rumors spread via short text services that the symptoms were due to bioterrorism [10]. A man sprayed an unknown substance into Maryland subway station, resulting in the sudden appearance of nausea, headache, and sore throat in 35 people. It was later determined that the bottle contained window cleaner [11]. Somatization disorders affecting 784 schoolchildren in separate incidents in the continental US and Alaska and 949 people over three districts in the West Bank all resulted from reports of "gas".

It is very difficult to estimate real values of losses caused by epidemics of fear and panic during bioterrorist attacks. The price could be very high especially in catastrophes with a pandemic character [12].

Categories of victims

Epidemiological studies in the aftermath of bioterrorist attacks have identified subpopulations at particular risk for severe outcomes. These include children, the elderly, those with chronic mental and physical illness, and those with limited social support [13].

Even within a single disaster settings, distinct subpopulations emerge. A role delineation model defines victims as primary victims – people directly exposed to a bioterrorist attack secondary victims – people with close family and personal ties to the primary victims; tertiary victims – people whose occupations require them to respond to a disaster; and quaternary victims – concerned and caring members of communities beyond the impact area.

Categories of psychological responses

Three categories of a population's psychological response to a bioterrorist attack and their needed interventions have been described.

Most people (the first category) may experience mild, transient distress such as sleep disturbance, fear, worry, anger, or sadness or increased use of tobacco or alcohol. Rather than labelling such psychological effects as «symptoms», which unnecessarily implies pathology for the experiences of individuals without psychiatric illness, language such as «reactions» or «responses» might better describe the normative, expected response to extraordinarily upsetting events. Persons experiencing such responses may return to normal function without treatment but might benefit from community-wide support and educational interventions.

A smaller group (the second category) may experience moderate symptoms such as persistent insomnia or anxiety or changes
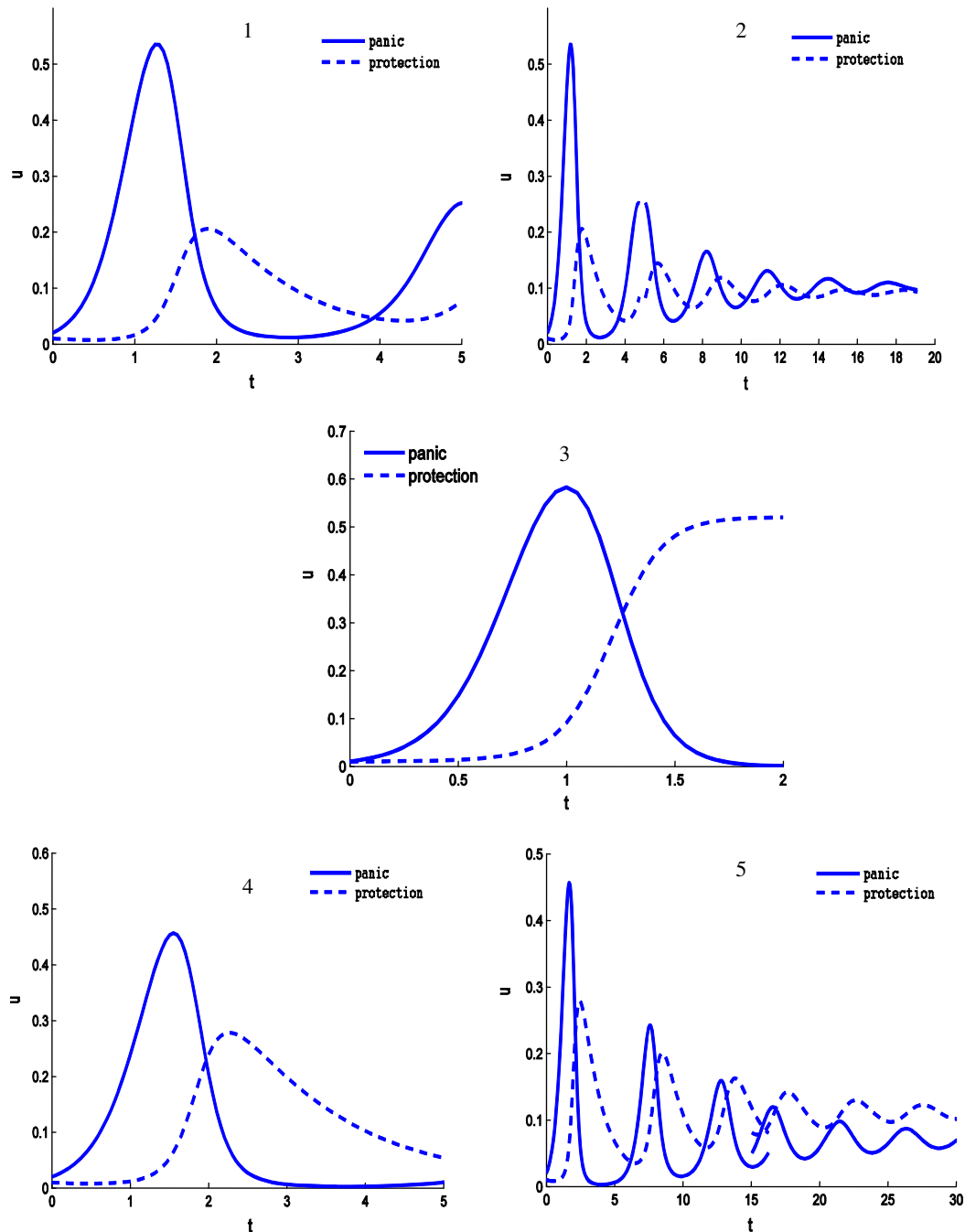
Fig. 1. Five hypothesized cases of change of panic and protection (*u*) during a bioterrorist attack, as a function of time (*t*).

in travel patterns or workplace behavior. Although these changes would not necessarily meet the threshold criteria for disease or disorder, such symptoms may affect work or home functionality. These symptoms will likely benefit from psychological and medical intervention.

A smaller subgroup (the third category) may develop psychiatric illness such as PTSD or major depression and will require specialized treatment [14].

Short-term consequences

Tyhurst [15] noted three phases in the course of a community response to disaster. The first or "impact", stage is the time from the onset of the acute stressors until they are no longer operant.

During this period, 12–25% of disaster victims are able to analyze the dangers, formulate a plan, and act on it. About 75% are stunned and bewildered, and the remaining up to 13% become confused, paralyzed by fear or anxiety, or hysterical. A population exposed to a terrorist attack experiences both direct injuries and numerous physical symptoms due to a prolonged stress, muscular tension, and sleep deprivation [16].

In the face of uncertainty, the general public would need reassurance, descriptions of the response measures under way, instruction on personal and collective protective measures, and messages of hope. On the other hand, the release of inaccurate, confusing, or contradictory information by leaders and/or the media has the potential to increase levels of fear, panic, and demoralization, as well as to discredit authorities. Health officials and emergency managers

should conduct massive campaign to educate the public through daily press conferences, regular media releases, a telephone hotline, Web-site updates, multilingual brochures and fliers, and personal contact at the epicenter of the outbreak. Gathering data on the most frequently asked questions could be one step toward building a more responsive public information strategy.

Long-term consequences

Long-term effects include phobias, sleep disorders, post traumatic stress disorder, substance abuse, and major depression [17]. When a bioterrorist attack destroys community, with dislocation and relocation of its members, additional stresses result from the loss of dignity as residents are forced into public shelters and experience the anxiety of strange environments and the disruption of their social networks [18].

To respond effectively to bioterrorist attacks, a comprehensive strategy needs to be developed regarding not only emergency response, but also long-term health care, risk communications, research, and economic assistance. Long term social and psychological effects may be worse than acute ones. The general level of malaise, fear, and anxiety may remain high for years, exacerbating preexisting psychiatric disorders and further increasing the risk of mass sociogenic illness [19]. During the second stage, a "period of recoil," which begins when the initial stresses have ceased or when the person has escaped, those involved have a great need to be with others and talk [20]. During this stage one form of crisis intervention, the critical incident debriefing may be initiated. During the final post-trauma stage, survivors realize what they have lost and the trauma they have experienced. Promises of aid and assistance that are made to a disaster-hit community by various agencies may lead to additional stress because of disappointment over unfilled or misunderstood promises and frustration with delays in receipt of aid.

Protection

Psychological preparedness to a bioterrorist attack in general population and in different social groups (e.g., health care workers) may have been overlooked. Dissemination of accurate, timely information may reduce unnecessary panic. Who delivers the message and in what interpersonal context may be just as if not more important than the message itself, [and] might result in better, more relevant, and perhaps more effective outcomes. It would not be helpful, for example, to tell the public that the danger is minimal if, at the same time, they are watching television footage of armed security forces in full biological protective clothing. Trust and credibility are key components of communication regarding a biological risk [21].

As was seen in severe acute respiratory syndrome (SARS) epidemic, frequent and detailed reports in the media on this newly emerging infection, helped people to form and rapidly change their perceptions about this disease in the absence of complete knowledge. Concerning human avian influenza, given a high fatality rate, the number of countries being affected, as well SARS experience it could be expected that an outbreak of the disease would result in a high level of psychological distress in the affected communities [22].

Epidemiologic models assigning an equal chance of spreading disease to each individual are unrealistic. In public health, like other fields, social networks facilitate dissemination of information. A central goal of health communication and health education is to devise efficient and effective ways to translate and disseminate health information to practitioners, communities and consumers, which could reduce disease risk and promote health. Health information is transmitted through and to health consum-

ers. Katz and Lazarsfeld proposed that the impact of media messages is mediated by social relationships. Not only did having a link to the source of information make a difference, but the composition of an individual's personal network and an individual's position within that network also had some relationship to knowledge and behavior. The role social networks play in health and health behavior is to build more effective community-based coalitions [23]. Protecting nation's health is a vital part of preserving national security and the continuity of critical national functions. Public health interventions can both limit distress and alter health risk behaviors (e.g., increased smoking and alcohol consumption). In this way, such information and education can restore communities, families, and workplaces and reduce a post-disaster mental health burden of distress and possible illness. One component of psychological first aid is the establishment of a sense of safety (e.g., through evacuation or protection from retraumatization) [24].

Psychological impact of false alarms and criminal hoaxes can be minimized by only responding to a credible threat. As a result of implementation of rigorous risk assessment by the police in the UK in the second part of October 2001 only 2.3% of reports of suspicious material led to a full scale response [25]. In other European countries between 22% and 100% and in the United States 15% of mail threats led to a similar response [26].

This may be the first essential step in promoting psychological preparedness within the community. Preparedness has to include understanding and monitoring of bioterrorism related perceptions and psychological responses. Experts should anticipate psychological responses, and anticipate avoidance behaviors in the event of a local bioterrorist act. With the likelihood of pandemic, the level of distress in a community cannot be determined by local factors only; panic in other countries may start a chain reaction. International efforts to reduce panic are warranted. It is interesting to see that even before the onset of a newly emerging infectious disease (SARS, human and avian influenza), people may change their behaviors (e.g., avoiding visiting hospitals because of fear of contracting avian influenza infection and eating less poultry meat). Such behavioral changes were associated significantly with anticipated distress and anticipated avoidance behaviors. With the onset of a human avian influenza outbreak in Hong Kong, more than 50% would adopt at least 4 out of the 5 avoidance behaviors studied. There is little doubt that a local economy would be affected, even at the onset stage of a local human influenza epidemic. It is likely that the level of distress would be enhanced in a vicious cycle, as seen in the SARS epidemic. It is very likely that even at the onset of a human avian influenza epidemic-regardless of whether it is a bird-to-human or human-to-human transmission-widespread distress, panic, and avoidance behaviors would occur in Hong Kong as well as in other affected countries.

As planning for responses to act of bioterrorism evolves, it is important to develop strategies that enlist public as an essential and capable partner. There is a very important role of nonprofessional individuals and groups in short-term and long-term responses to disasters with mass casualties. Involving public will require the raise of awareness of its roles and responsibilities concerning a bioterrorist attack.

Conclusion

We have proposed a mathematical model of panic and protection as function of time in a population exposed to a bioterrorist attack and response to it. This model might be helpful for a community to timely and properly apply counter-measures and to minimize human mental suffering during a bioterrorist attack.

Acknowledgements

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