Rev. sci. tech. Off. int. Epiz., 2006, **25** (1), 353-360

It is hard to predict the future: the evolving nature of threats and vulnerabilities

G.A. Ackerman

WMD Terrorism Research Program, Center for Nonproliferation Studies, Monterey Institute of International Studies, 460 Pierce St, Monterey, California, 93940, United States of America

Summary

This paper describes the evolving nature of threats and vulnerabilities associated with biological disasters with animal origins, and introduces some of the pitfalls and opportunities associated with anticipating future threats. Evolving threats and vulnerabilities include continued deforestation and encroachment on virgin habitats, the effects of globalisation on trade and transportation, the increased interdependence and social vulnerability of modern society, the commingling of intensive agriculture and traditional farming methods, the periodic appearance of pandemics and epizootics, and indications that numerous human actors are displaying an increasing interest in and capability of using biological agents as weapons. These developments must be viewed in the context of various impediments to accurately gauging future threats, such as the appearance of new elements that depart from current trends and the inherent difficulty in anticipating human, and especially terrorist, behaviour. The paper concludes with some broad recommendations for structuring a policy response to the threat in an environment of uncertainty about the future.

Keywords

Emerging disease – Epizootic – Foreign animal disease – Pandemic – Prediction – Simulation – Terrorism – Threat assessment.

Introduction

'Prediction is very difficult, especially about the future.'

Niels Bohr (1885-1962)

'For man does not even know his hour: like fish caught in a fatal net, like birds seized in a snare, so are men caught in the moment of disaster when it falls upon them suddenly.'

Ecclesiastes 9:12

The previous offerings in this volume have described the dangers stemming from biological disasters with animal origins and what is currently being done at both national and international levels to address the threat. Yet, looking forward, we are confronted with myriad uncertainties. The future is an 'undiscovered country' that lies forever just beyond the horizon of our perceptions and our present efforts. Where will a new major epizootic or pandemic arise, and what social and political environment will it emerge into? Who will pose the greatest bioterrorist threat in the next twenty years, and how do we stop them? As responsible actors in the fields of animal and public health, we cannot sit on the sidelines with a smug fatalism and provide hollow commentary after a biological disaster occurs. We place upon ourselves the burden of ameliorating some of the worst possible futures by preparing and planning for biological disasters. Thus, no matter how difficult this may prove, we are forced to explore the nebulous region of future environments and events. This paper will describe the evolving nature of threats and vulnerabilities associated with biological disasters with animal origins, and introduce some of the pitfalls and opportunities related to anticipating future threats.

Before embarking on the discussion, it is necessary to draw a distinction between two generic types of prediction that occupy opposite ends of a continuum. 'Strategic prediction' seeks to describe general trends and the existence and magnitude of future threats, whereas 'point prediction' focuses on the precise nature of future events, such as their exact timing and location. Generally speaking, the closer one moves towards seeking point predictions, the more difficult the enterprise of anticipation becomes. One must therefore be cognizant of the level or 'granularity' of prediction required for any particular question about the future, since it is not always necessary to expend a large amount of resources on attaining point predictions when strategic predictions will suffice to guide a particular policy decision.

Evolving threats and vulnerabilities

Several of the authors who have contributed to this volume – like many other contemporary experts – have alluded to a variety of important dynamics related to biological disasters with animal origins. To the extent that the past is a valid guide to future possibilities, these dynamics could yield perceptible patterns that are manifest as either ongoing trends or cyclical repetitions of past events. The following discussion is hardly comprehensive, and each element has been discussed in detail elsewhere, but the list should give the reader some idea of current phenomena that might contribute towards the future threat of biological disasters with animal origins.

Continued deforestation and encroachment on virgin habitats

Population pressures in many developing countries, together with increased demand for natural resources, suggest that current levels of deforestation and encroachment on natural areas are likely to continue, at least for the foreseeable future. Human beings have had little or no former contact with some of these areas (such as virgin rainforests in the Amazon or central Africa) and, as human settlement moves into these areas, the probability of hitherto unknown pathogens crossing over from indigenous wildlife to large human populations increases. Several serious human diseases (including human immunodeficiency virus, filoviruses such as Ebola, and arenaviruses such as Lassa and Machupo) are believed to have originated in previously remote areas and then crossed over to the human populations that have encroached on these areas, often through an animal vector. The emergence of a particular new pathogen could be regarded as a 'wild-card' event that cannot be predicted with accuracy; the environmental conditions that increase the likelihood of such an event do however constitute a discernible trend.

Globalisation: transportation and trade

The growth of global markets and the dramatic increases in flows of goods, animals and persons across national borders are often accused of causing harmful side effects. One area where such concerns are well founded is global public and animal health. Globalisation has made it far more difficult to keep animal diseases from spreading, and almost impossible to keep highly infectious human diseases contained. Previous global pandemics, such as the Black Death or the Spanish flu, took years or months to spread across far-flung geographic regions. Air transportation and uncontrolled immigration flows mean that today a pathogen could spread globally in a matter of days or weeks. Recent experience with SARS (which is less infectious than many other organisms) and avian flu indicate the difficulties associated with containing disease outbreaks in the 21st Century. Barring remedial measures such as greatly enhanced surveillance and international controls, the speed with which a highly infectious agent could spread worldwide is unlikely to decrease in coming years.

Increasing societal vulnerability

In addition to increased global interconnectedness, there are several aspects of modern society that arguably increase its vulnerability to biological disasters. These include:

– the growing dependence on networks that can fail catastrophically

– increased urbanisation and local population densities

– widespread use of antibiotics (in both animals and people) leading to increasing antibiotic resistance

– the ossification of public health and veterinary capabilities in many countries.

Moreover, many developed nations have not experienced a major human or animal disease outbreak in over half a century and their publics and governments are unused to coping, both politically and socially, with large-scale infectious disease. In short, the trend seems to be moving along the direction of greater societal vulnerability to either intentional or naturally occurring biological disasters, including those with animal origins.

Compromised immunogenesis and availability of treatment

A number of factors are contributing towards a diminution in the levels of immunity to disease. Increasing microbial

resistance to antibiotics and lower vaccination rates in ever denser populations are two areas of concern. The developing world faces particular problems in this regard, as famine and malnutrition negate immunogenesis (which may have been, for example, a complicating factor in the severe symptoms observed in the East African Rift Valley fever outbreak in 1997 to 1998) and pharmaceutical research continues to focus on more profitable treatments for maladies in the 'First World' (the so-called 'orphan disease' phenomenon).

Intensive agriculture and traditional farming

The rise in intensive farming methods in the livestock industry, including the centralisation of animal markets and high-density livestock rearing, has been singled out as an important contributor to disease outbreaks. Proponents of such farming methods have countered that it is traditional farming methods in which different species are raised in close proximity that facilitate pathogen mutations that cross the species barrier and lead to new outbreaks. We may indeed be getting the worst of both worlds – traditional farming that is still practised in many parts of the world, such as Asia, can precipitate new pathogens, while intensive farming practices can allow the new disease to spread quickly. The combination of two very different farming methods may therefore be making us increasingly vulnerable to emerging disease.

Periodic pandemics/epizootics

The above trends can also be viewed in a historical context. The past century has borne witness to periodic global outbreaks of certain diseases, such as influenza. Until we discover exactly how and why such pandemics and epizootics periodically reoccur, we would be foolish to believe that this pattern will not continue.

The increasing motivation and capabilities of non-state actors to use biological agents as weapons

The past decade has revealed an increasing interest by a variety of terrorist and other groups, from religious fanatics like Al-Qaeda to apocalyptic cults, in using biological weapons. This is reflected by many cases in the Monterey WMD [weapons of mass destruction] Terrorism Database (9). Thus far most of their attempts have ended in failure, as exemplified by the Aum Shinrikyo cult's series of unsuccessful attempts to use biological weapons. As the old adage goes, however, where there is a will there is a way; the successful preparation of weapons-grade anthrax spores by the unknown perpetrator of the 2001 'anthrax letter' mailings in the United States of America suggests that at least some terrorists or other nefarious state or non-state actors could soon attain a biological weapons capability. It is certainly conceivable that these actors might employ or target animals as part of their implementation of a bioterrorist attack. The effects of technological advances and ideological shifts on terrorist capabilities and motivations must be carefully considered. For example, rapid developments in synthetic biology and the advent of microbiological 'kits' may facilitate the capabilities of both state and non-state actors in this regard. Moreover, an assortment of persistent and burgeoning factors, from resource scarcities to intractable ethnic and religious disputes, means that general levels of conflict are hardly likely to decrease over the next twenty years. All else being equal, the greater the number of disaffected individuals, organisations and countries that resort to violence, the greater the probability that at least some will embrace biological attacks as a tactic.

In addition to the ominous (although by no means determinative) dynamics listed above, there is also the possibility of serendipitous events, so-called 'wild-cards', which could heighten the possibility of biological disasters with animal origins. An example would be the accidental or intentional production of completely new and incredibly virulent pathogens as a result of advances in synthetic biology. On the other hand, developments in fields such as synthetic biology could also lead to radical new treatments or prophylaxes that drastically reduce the threat of biological disasters.

Another factor that must be considered is that the actions of governments and the international community can have a large impact on the scale of the future threat. For instance, if governments adopt shortsighted and obstructionist approaches to disease surveillance (as several commentators have accused the People's Republic of China of doing in recent years), the threat of biological disaster will increase, whereas closer international cooperation and an increase in the resources devoted to monitoring both animal and human disease could greatly reduce the threat. Equally, the manner in which governments approach socio-political grievances at both the domestic and international levels can dramatically influence the number of would-be perpetrators of violence, including those who might choose to utilise biological means.

Impediments to anticipating future threats

Having considered some of the apparent trends in threats and vulnerabilities related to biological disasters with animal origins, policy-makers might be tempted to jump to

hasty conclusions. Before either overreacting or dismissing the trends as fantastic doomsaying, we need to take a step back and examine the very notion of prediction itself. There are a series of impediments, both conceptual and practical, which hamper any attempt to predict the nature of future biological disasters accurately. It is only by better understanding these that we can begin to address them and approach threat anticipation more wisely. The most important of these impediments are discussed below.

The fundamental unpredictability of certain classes of events

Most of us are aware of the basic epistemic distinction between 'those things we know that we don't know' and 'those things we don't know that we don't know', and recognise that the latter present more of a problem than the former. However, policy-makers often fail to realise that, when dealing with certain domains and systems, there are things that we absolutely cannot know. Philosophers and mathematicians have long known that truth in some systems cannot be attained (see, for example, Gödel's Incompleteness Theorems [5]), but such concepts have only appeared relatively recently in the biological and social sciences, with the broader application and publication of theories of chaos and complexity. For general, non-technical introductions to these topics, see James Gleick (4) and Mitchell Waldrop (13). David Snowden and Cynthia Kurtz, in their award-winning paper 'The new dynamics of strategy: sense-making in a complex and complicated world' (7), describe both the complex domain, in which patterns can emerge and be perceived but cannot be predicted, and the chaotic domain, which is devoid of cause and effect. The important implication of this for policy-makers is that if a question or aspect of a question (such as 'Where will the next major epizootic occur?') resides in one of these domains, the best strategy is not to attempt to predict an answer, but rather to ameliorate the threat by probing or shaping the environment in which the threat might arise.

Signals versus noise

There is currently more information available to scientists and policy-makers than ever before, from huge genomic databanks to myriad news and scientific publications. The sheer volume of information makes it impractical for any individual to monitor every possible information source to detect early signs of impending disaster, even if we knew what signs to look for. Those seeking to predict future threats therefore must rely on information sharing, extensive collaboration, and automated tools. Unfortunately, none of these, whether alone or in combination, has thus far been implemented in a manner that would comprise a robust method for finding the needle of true threat in the haystack of superfluous data.

The past as an indicator of the future

Most anticipation of future threats is based either implicitly or explicitly on extrapolation from past events. There is a variety of opinions on the utility of relying on past observables as indicators of future probabilities, ranging from viewing the past as an indispensable guide to the future to believing that concentrating on past experiences is, to quote the philosopher Nassim Nicholas Taleb, like 'drivers looking through the rear view mirror while convinced they are looking ahead' (11), so that we are blind to substantial future changes. The objective state of affairs probably lies somewhere in between. While the philosophers Thomas Hobbes and David Hume did a good job of highlighting the perils of induction (deriving general rules from a finite number of observations), there are many trends that are both observable and consistent, such as the worldwide increase in urbanisation with concomitant specific implications for public health. Past and present events can serve therefore as one (not the only) guide to anticipating future biological disasters, as long as one bears the following caveats in mind:

a) threats, especially in the biological realm, which includes such phenomena as rapid mutations of infectious organisms, are dynamic. If future disasters will look very different from those of today, we must be careful not to act like the proverbial generals fighting the last war by preparing responses applicable only to past disasters;

b) in many cases, the sample size of previous events for a particular threat is zero and we cannot rely on the past at all; for instance, no terrorist has ever synthesised a pathogen from scratch, but this does not mean that it will not happen. We must be especially cautious about using similar events as proxies, since the variance of outcomes presaged by indicators that differ only in seemingly minor aspects can be substantial;

c) in using past events, we often place undue emphasis on past observables: that is, we impute causation to those factors which we are able to measure and for which we have data. Since many less tangible aspects of historical cases are not recorded, we can develop false trend models and expectations of future events.

Outliers and discontinuities

Related to the above discussion is the very consequential impact of sudden, unexpected events that constitute radical departures from previous trends and experience. Although an extensive discussion of this topic is outside the scope of this paper (10, 11), any attempts at prediction must take into account so-called 'wild-cards', surprises and other rare events. This is compounded by the fact that these unexpected events often have large (and deleterious) impacts precisely because we are not prepared to respond to them. As William Freudenburg warns us, 'there is a

possibility that as time goes by and very rare and catastrophic events do not occur, an agency's risk assessors may begin to disregard the risk of those types of events entirely' (3). The sudden appearance of a new pathogen or the emergence of a terrorist group with completely novel characteristics are two examples of outlier (unpredicted and atypical) events that can have devastating consequences. One general strategy for dealing with such events is to develop flexible response plans that can adapt to a wide spectrum of threats, even those that are quite different from what we might expect.

Predicting human behaviour

The obstacles to threat anticipation mentioned above apply to all events, whether intentional or 'naturally' occurring. There are, however, several aspects of intentional acts by human beings that make prediction especially difficult and that come into play in any consideration of bioterrorism. First, human threats are even more dynamic than evolutionary factors, in that human beings can adapt their behaviour instantaneously, can strategise to avoid defences and can concentrate their efforts on vulnerabilities. Second, human beings display an exquisite diversity of action rarely observed in the natural world, with innovation a common occurrence amongst human adversaries. Lastly, while many natural processes are quite well understood and at least relatively well defined, the study of human mental processes is in many ways still very primitive, with few well-defined features and hardly any predictive tools with general application.

The extreme case of extremist behaviour

General difficulties in predicting human behaviour are exacerbated in the case of extremists such as terrorists, who are particularly wily and adaptive and often have obscure motivations for action. The most obvious (and serious) complication stems from the fact that terrorists and many other dangerous actors, by their very nature, operate clandestinely, thus making proactive identification and data collection especially difficult for the threat assessor.

Untangling the threads

It may appear that, with apparent trends that may or may not be indicative of future threats and the possibility of unforeseen factors that we do not or even cannot discern, we are left on even less solid ground than we were at the beginning of this paper. In fact, following Confucius' dictum that 'real knowledge is to know the extent of one's ignorance', we are now far better equipped to understand the uncertainties of the future and incorporate them into our decision making. In this vein, the following recommendations are offered as high-level approaches for dealing with future biological threats, including those with animal origins.

Do not ignore current trends, but approach them judiciously

Despite the caveats about relying on extrapolations of past and current events, these can at least provide a baseline from which to explore future threats. Many of the trends pertaining to biological disasters carry with them significant probabilities of continuing and are thus important, so long as we do not allow our thinking to be constrained by existing patterns. Paying attention to current trends, while remaining sensitive to outlying possibilities and non-linear dynamics, is thus a prudent strategy.

Manage, rather than try to eliminate, uncertainty

Once we come to terms with the fact that uncertainty is a pervasive element in any predictive effort, we can incorporate uncertainty into our strategies and policies, rather than attempting to minimise or eliminate it. This can include structuring preparations and responses to biological disasters to cover a broad range of possible events, including wild-cards and other currently unforeseeable possibilities. This argues for greater weight to be placed on robust, broad and holistic approaches to animal and public health instead of specific fixes to the particular threat (or disease) that is currently most prominent in the minds of the public or policy-makers.

Simulation can be a helpful tool

One way in which we can examine a variety of possible futures, in terms of looking at both the landscape of possible threats and the efficacy of alternative responses, is to use simulation of various types. Current approaches to simulation include mathematical epidemiological modelling (1) and agent-based computational simulation (see for example Epstein *et al.* [2]). One recent and quite promising development is the increasing attention paid to the social and political aspects of potential disease outbreaks, in addition to the health and economic effects. Prototypes of this are the EpiSims Project at Los Alamos National Laboratory and the BioWar Project at Carnegie Mellon University. While most current simulation efforts are aimed at the spread of disease amongst human populations, many of these same techniques can be applied to animal disease outbreaks and animal-to-human transmission. One area requiring further development is

the simulation of terrorist decision-making and targeting choices, although this has received renewed attention in the past five years.

Situational awareness is crucial

In order to confirm current trends and provide early indications of radical departures from expectations, more work will be needed to address the signal-to-noise problem that was discussed earlier. In the context of biological disasters with animal origins, this could require new thinking regarding disease surveillance, such as probability-driven active surveillance – where risk analysis would identify periods of heightened danger and would initiate specific active monitoring efforts – in place of the current predominance of passive disease surveillance measures (12).

Concluding thoughts

Disease outbreaks in the past, both in animals and humans, have not only damaged people's health and livelihoods; on occasion they have wrought irreparable damage on entire societies, undermining long-held social beliefs and overturning stable political systems (6, 8). While human and animal populations eventually recover from such upheavals in most cases, the cost in lives, productivity and suffering is often great. Threats of future biological disasters may be impossible to predict with any degree of certainty, but if we proceed cautiously and utilise all available tools, we can provide ourselves with far better guidance about where to allocate resources to prevent and mitigate such outbreaks. Much work, however, remains to be done in assessment of threats in this area, and the author hopes that the current volume can help foster greater understanding of the likelihood and possible consequences of biological disasters with animal origins among the policy-making community. It is through understanding and a proactive orientation towards this threat that we can prepare, to the best of our ability, for whatever the future may bring.

Il est difficile de prédire l'avenir : des menaces et des vulnérabilités en évolution constante

G.A. Ackerman

Résumé

Le présent article décrit le caractère fluctuant des menaces et des vulnérabilités en matière de catastrophes biologiques d'origine animale, et présente certains écueils et possibilités associés à l'anticipation des menaces futures. Les nouvelles menaces et les vulnérabilités sont constituées, entre autre, par la poursuite du déboisement et de l'empiètement sur les habitats naturels, les effets de la mondialisation sur le commerce et les transports, l'interdépendance accrue et la vulnérabilité sociale de la société moderne, la coexistence des méthodes de culture traditionnelle et d'agriculture intensive, l'apparition périodique de pandémies et d'épizooties, et la constatation que nombre

d'acteurs affichent des capacités et un intérêt accrus pour l'utilisation d'agents biologiques en tant qu'armes. Ces phénomènes doivent être considérés dans le contexte des diverses entraves qui empêchent d'évaluer avec exactitude les menaces futures, telles que l'apparition de nouveaux éléments qui se démarquent des tendances actuelles et la difficulté intrinsèque que représente l'anticipation du comportement humain, en particulier terroriste. L'article conclut par des recommandations générales permettant de structurer une riposte à la menace dans un climat d'incertitude quant à l'avenir.

Mots-clés
Appréciation de la menace – Épizootie – Maladie animale exotique – Maladie émergente – Pandémie – Prédiction – Simulation – Terrorisme.

Las dificultades de predecir el futuro, o la cambiante naturaleza de las amenazas y los puntos vulnerables

G.A. Ackerman

Resumen
El autor describe el carácter cambiante de las amenazas y los puntos vulnerables en relación con los desastres biológicos de origen animal, y expone algunas de las dificultades y oportunidades ligadas a la predicción de futuras amenazas. Entre otros peligros y puntos débiles que van cambiando continuamente, cabe destacar la incesante deforestación y la invasión de hábitats vírgenes, los efectos de la mundialización sobre el comercio y los transportes, el mayor nivel de interdependencia y fragilidad social de las sociedades modernas, la mezcla de métodos de agricultura intensiva y tradicional, la eclosión periódica de pandemias y epizootias, y los indicios de que muchos grupos muestran un creciente interés por utilizar agentes biológicos con fines bélicos y están adquiriendo la capacidad de hacerlo. Para tener en cuenta esta evolución hay que colocarla en un contexto en el que diversos obstáculos impiden evaluar con exactitud las futuras amenazas, por ejemplo la aparición de nuevos elementos que divergen de las tendencias actuales y la dificultad de predecir el comportamiento humano, sobre todo en el caso de terroristas. El autor concluye formulando una serie de recomendaciones generales para estructurar una respuesta política a las amenazas en un contexto de incertidumbre respecto al futuro.

Palabras clave
Enfermedad animal foránea – Enfermedad emergente – Epizootia – Evaluación de amenazas – Pandemia – Predicción – Simulación – Terrorismo.

References

1. Castillo-Chavez C., Blower S., Van Den Driessche P., Kirschner D., & Yakubu A. (eds) (2002). – Mathematical approaches for emerging and re-emerging infectious diseases, Parts I and II. An introduction to models, methods, and theory. IMA Volumes in Mathematics and its Applications. Springer-Verlag, New York, Volumes 125 and 126.

2. Epstein J., Cummings D.A.T., Chakravarty S., Singa R.M. & Burke D.S. (2004). – Toward a containment strategy for smallpox bioterror: an individual-based computational approach. Brookings Institution Press, Washington, DC.

3. Freudenburg W.R. (1992). – Heuristics, biases, and the not-so-general public: expertise and error in the assessment of risks. *In* Social theories of risk (S. Krimsky & D. Golding, eds). Praeger, Westport, Connecticut, 229-250.

4. Gleick J. (1988). – Chaos: making a new science. Penguin, New York.

5. Gödel K. (1931). – Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme, I (Over formally undecidable sets of the Principia Mathematica and related systems). *Monatsh. Math. Phys.,* **38**, 173-198.

6. Gottfried R.S. (1985). – The Black Death. Free Press, New York.

7. Kurtz C.F. & Snowden D.J. (2003). – The new dynamics of strategy: sense-making in a complex and complicated world. *IBM Systems J.*, **42** (3), 462-483.

8. McNeill W. (1998). – Plagues and peoples. Anchor, New York.

9. Monterey Institute of International Studies (2005). – Monterey WMD terrorism database. – Available at: cns.miis.edu/wmdt/ (accessed on 4 April 2006).

10. Petersen J.L. (2000). – Out of the blue. Madison Books, Lanham, Maryland.

11. Taleb N. (2006). – The black swan: how the improbable rules the world and why we don't know it. Random House, New York (forthcoming).

12. Thurmond M.C. (2003). – Conceptual foundations for infectious disease surveillance. *J. vet. diagn. Invest.*, **15** (6), 501-514.

13. Waldrop M.M. (1992). – Complexity: the emerging science at the edge of order and chaos. Simon and Schuster, New York.