

Emerging Diseases: A Global and Biological Perspective

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Summary

The 'Livestock Revolution' and globalization with enormous increases in free trade of animals and food products are not a choice but a reality (Thiermann, *J. Vet. Med. Educ.*, **28**, 2001, 56). Conditions of modern life, some of them related to or being the result of globalization, ensure that factors responsible for disease emergence are more prevalent than ever. Categorization of the factors is somewhat arbitrary but are representative of the underlying processes that cause emergence. Major responsible factors include ecological changes, such as changes due to agriculture or economic development or to anomalies in climates, human demographical changes and behaviour, travel and commerce, technology and industry, microbial adaptation and change, and the breakdown of public health measures (Morse, *Emerg. Infect. Dis.*, **1**, 1995, 7). Furtheron, concerning pathogens, their most striking feature emerging and re-emerging is their diversity, ranging from viruses and prions, over bacteria and rickettsia, fungi, protozoa to helminths. As presently the epidemiological perspective does not permit reliable prediction and prevention of most damaging new pathogens, and as the evolutionary perspective only provides rough theoretical estimates for selective processes in pathogen populations, surveillance and monitoring remain the most important methods to recognize early that 'something has happened'. In light of the complexity and diversity of likely new emerging diseases, such surveillance may be more broadly targeted and aimed more realistically at early recognition of disease syndromes rather than at identifying microbial diseases. The complex and rapid-paced development of international trade, coupled with increasing societal demands for not only abundant and inexpensive food as well as for protection from diseases originating from animals, demands immediate attention from the veterinary community. The inter-relationship at the minimum between animal production, animal diseases and human diseases demands that we consider our concepts, methods and structures. There exists a huge growth area for the veterinary profession; substantial need exists for trained individuals who understand the science of foreign diseases, who can facilitate emergency management operations against diseases (Brown, *J. Vet. Med. Educ.*, **30**, 2003, 112) and who can contribute to adjust and strategically develop animal production systems further.

Introduction

During the past 25 years, the quantity of meat consumed in developing countries grew three times as much as in developed

countries. This trend is forecasted to continue; it is estimated that demand for meat and milk products will double over the next two decades in the developing world. Delgado et al. (1999) estimate the annual demand for meat in the developing world to grow from 111 million tons in 1997 to 213 million tons in 2020. Over the same period, milk consumption would grow from 194 million tons to 324 million tons per year in the developing world. This demand-driven increase in animal agriculture, termed 'Livestock Revolution' (Delgado et al., 1999) will have to come from expanding intensive rearing systems in the developing world. The sector will shift from a resource (feed availability) driven system to a demand driven system, from a roughage based system to a cereal based system; livestock will lose much of its multi-functionality, and will be mainly kept for meat and milk (De Haan, 2001). The Livestock Revolution might crowd out a large number of smallholder livestock keepers, thus eliminating one of the most powerful approaches to rural poverty reduction for more than 600 million rural poor. The crowding out is already occurring in many middle-income countries, where there is a strong concentration of production and processing (De Haan, 2001). Intensified or even industrialized production implies that agriculture is decoupled from the surrounding natural environment; systems are characterized by integration of input supply, food commodity production, processing and marketing. Monogastric animals (pigs and poultry) will be the most important source of growth; monogastric animals have a better concentrate feed conversion than ruminant animals; their production technology further is more universal and thus more amenable to large-scale operations.

The concentration of animals in industrial operations greatly increases disease transmission risks. At the same time, increased global trade increases the spread of diseases. Animals and animal products are crossing borders with logarithmically greater frequency than what it was even a decade or two ago (Brown, 2003). The global risk of foreign, emerging and re-emerging animal diseases subsequently has increased in recent years. Most publicly noted were the 2000–2001 foot-and-mouth disease outbreaks in Europe, South America, Asia and Africa, the worldwide continuing outbreaks of highly pathogenic avian influenza since 2003–04 and the 2002–03 Newcastle disease outbreak in the USA. New diseases transmitted from animals to humans under natural conditions (zoonoses) also have increased in numbers. Examples include bovine spongiform encephalopathy, West Nile virus, Hanta virus, Nipah virus, Sars and Hendra, Menangle and Lyssa viruses.

The Livestock Revolution accompanied by increased worldwide trade of animals and animal products thus offers opportunities but also carries the threat of several negative effects. Diseases not only have increased in numbers, but their spread worldwide also has become easier. Several underlying factors inherent in modern society are responsible for the increase of emerging diseases, notably the expansion of the human population, increase in traffic of people, animals, and animal products, environmental changes and, animal species interface and husbandry and technological changes.

The situation of the transboundary nature of these (animal) diseases and their potential to overcome species barriers and to affect humans poses such alarming and unprecedented challenges that a number of scientists like Kuiken et al. (2005) and CAST (2005) point to the enormous impact of emerging infections on public health, food supply, economies, and the environment and suggest, at the minimum, a better integration among surveillance systems in humans, domestic animals and wildlife.

Animal health issues are no longer related to only animal agriculture, they are embedded in cultural, political and economic factors that impact the global risk of animal diseases. These social, political and economic impacts can by far outgrow the technical aspects of diseases and control of animal diseases.

There is a certain urgency that we address this area newly, but the task is extremely difficult because of the complexity of factors we are faced with. Agriculturalists and veterinarians must understand animal diseases in a new context. Globalization and the likelihood of emerging diseases have generated a sort of future shock for the veterinary profession to which it still has not found convincing answers.

To widen the discussion on diagnostic tools and technology, this paper in a spotlight fashion summarizes some aspects out of the global and biological arenas. A wider picture may enter discussions to better grasp the dimension of the problem, what developments in the near future can be expected and, consequently, what options for improved control of diseases do exist or will have to be developed.

The Global Scenario

The Food and Agriculture Organization of the United Nations (FAO, 2005) summarized the present and future scenario as follows: "In 1980, the human population of developing countries made up 76% of the world population and consumed one-third of the world's meat and milk. By 2020, they may account for 80% of the world's population but two-thirds of direct consumption of meat and 60% of milk consumption. Livestock production traded across international borders has increased from 4% in the early 1980s to approximately 10%. Liberalized international markets with decreasing tariffs, 'tariffication' of non-tariff barriers for some products and expanding membership of the World Trade Organization (WTO) encourage globalization of the livestock sector by 'levelling the playing field' for all trading partners. Globalization integrates the economies through trade, flows of finance, knowledge, ideas and people. It is associated with a dynamic structural shift towards increased market orientation and integration, larger scales, geographical concentration and intensification. In value terms, several developing countries – notably Brazil, China

and Thailand – today are among the top 20 exporters and importers of livestock products".

Under the principles of WTO's Sanitary and Phytosanitary agreement, it is easier for countries with similar (or known) disease status to trade with each other. Outbreaks of transboundary diseases and new threats of emerging diseases cause disruption within national markets and regional trade groups as well as for international trade. The demand-driven 'Livestock Revolution' and 'Rule-Based Trade' are the two major drivers of globalization, interconnecting livestock industries, societies and cultures but also disease agents.

The wanted and continuing consequences of globalization thus are accompanied by e.g. unintended animal disease consequences the future dimensions of which are largely unknown.

One result of the occurrence of recent emerging or re-emerging diseases though is most apparent. These diseases involve larger populations, entire countries or several countries and involve tremendous costs. If we look at the current avian influenza disaster to which as of yet there is no end and most forecasts predict a further spread to more countries, costs simply involved with the animal component of the epidemics, excluding human components, make it the most expensive animal disease ever.

Epidemics-in-Waiting

An updated literature survey identified 1407 recognized species of human pathogens (Taylor et al., 2001; Woolhouse and Gowtage-Sequeria, 2005). The surprising and troubling fact is that more than 58% of the human pathogens are agents which come from animals, i.e. they are zoonotic. A total of 177 species (13%) are regarded as emerging or re-emerging, the majority being viruses (77 species), followed by bacteria (54), fungi (22), protozoa (14) and helminths (10). Within viruses, RNA viruses dominate, comprising 37% of all emerging and re-emerging pathogens. RNA viruses are prominent among the subset of pathogens that have entered the human population in the past decades, such as HIV or the SARS coronavirus. Ungulates are the most important type of non-human hosts, followed by carnivores, rodents, non-mammals, primates, other mammals and bats.

There are further wild animals, 15 000 species of mammals and birds alone worldwide. What diseases and how many are harboured by wildlife are still largely unknown, pathogen surveillance in wildlife is not intensive to nonexistent, particularly in developing countries.

Likelihood of Transmission

The possible magnitude of an infectious disease outbreak is related to the basic reproduction number R_0 of a pathogen. R_0 is the average number of secondary infections produced by a single primary infection introduced into a large population of previously unexposed hosts. Antia et al. (2003) and Woolhouse and Gowtage-Sequeria (2005) hypothesize that for pathogens that are moderately transmissible within human populations (corresponding to R_0 approximately 1) outbreaks are possible upon small changes in R_0 . Small changes in the nature of the host-pathogen interaction can lead to large increases (or decreases) in the scale of the public health problem. An obvious reason for this is that it takes less change

to achieve an R_0 of more than one if the initial R_0 is just below one. A less obvious reason is that the length of time a pathogen persists in the population before disappearing increases with R_0 (Bull and Dykhuizen, 2003); pathogens with R_0 nearly at unity can persist for a considerable time by chance. The longer the pathogen persists, the greater will be its opportunity to evolve into a higher R_0 . Bull and Dykhuizen (2003) suggest that even with existing technology, methods could be developed for monitoring emerging pathogens, potentially distinguishing between strains with differing R_0 values. The means provided by Antia et al. (2003), of identifying these epidemics-in-waiting could become a critical tool in a global defence strategy against emerging pathogens.

Model for Emergence of Zoonotic Diseases

An excellent representation of the complex web of interactions that can result in the emergence of zoonotic diseases and other infectious diseases is provided by the 'convergence model' of the American Institute of Medicine (IOM, 2003). The model graphically groups and overlays 'risk factors', being ecological factors, physical, environmental factors, genetic and biological factors and social, political and economic factors that determine whether an outbreak of an infectious disease is to occur or not. The central component of the convergence model is contact between humans and biological pathogens. Some risk factors favouring disease occurrence by increased contact due to humans are known, like when ecological and social, political and economic factors are disrupted; other risk factors are suspected, like when physical, environmental, ecological and genetic or biological factors in some intensity and sequence exert their influences on pathogens. However, other risk factors still are a closed book, particularly when the interplay of the multitude of factors out of the different areas is concerned.

In consequence, it is virtually impossible to predict the nature of the next outbreak or its precise location (WHO, 2004).

Intensive Animal Agriculture and Breed Diversity

Increasing global demand for animal products can only be met by intensification of production, given the very limited scope for extending the area of land suitable for agriculture (Upton and Otte, 2004). For the same reason, intensification is the only way of raising the incomes of people engaged in agriculture. More industrialized livestock production requires genetically uniform stock, which contributes to an erosion of domestic breed diversity as local breeds are 'crowded' out by so-called modern breeds (FAO, 2001). From the 3237 existing livestock breeds in 1992, 617 breeds have become extinct since 1982, another 474 breeds are considered to be rare and endangered (Cip-Upward, 2003). It is suggested that within a period of 100 years about 28% of livestock breed withered, became extinct or rare or endangered. Extreme examples are that almost all pigs reared under commercial farming systems in Europe and North America belong to only two or three breeds. Ninety per cent of all North American dairy cattle and 60% of all European cattle belong to only one breed, the Holstein. Organized poultry farming across the world relies on a few multinational companies who have developed a handful

of breeds for their supply of stock (Tisdell, 2001). Such narrow genetic bases pose many inherent dangers. A narrow genetic base selected for a particular favourable production trait may be unsuitable to, for example, emerging disease problems and changes in climates (environmental tolerance).

Intensive or Alternative Animal Agriculture

In the European Union, intensification or industrialization of animal agriculture is seen very critically. Multifunctionality, organic farming and sustainable agriculture rather are seen as foundations for the European model of agriculture as a whole (Béranger, 2000). Doubts exist whether this model of agriculture of affluent countries with surplus production of foods can be taken particularly for developing countries with shortages of foods and very few alternatives to agricultural products to enter international markets. Intensive production for these countries in the short term successfully meets demands of populations for food products at economic prices. The hidden costs of such systems like demanding huge feed imports, environmental degradation and concerns over animal welfare present all involved in animal production, processing and marketing with a plethora of interlinked problems and challenges of far-ranging significance. If this intensification is to be sustained or further increased, it will need mechanisms for effective coordination and collaboration at the international level. The foundation and chances for any success will lie in the availability of policies that are realistic and respected by all and not unduly influenced by one-sided and short-sighted economic interests. Realistically, crowding of animals into intensive units coupled with a further rise in international trade for some time will continue to exacerbate risks of new emerging diseases, food borne diseases and zoonoses.

Epidemiological Approach

The interaction of determinants (host, environment and agent) that brings about a disease situation in animals and man is a system that is continually changing. Epidemiologists try to assess these complex situations by using e.g. probability theory. Probability estimates change with increasing information; they tell us whether something will happen. Possibility estimates on the other hand tell us whether something can happen. Usually, when the possibility of an event is decreased, so is its probability but the reverse is not necessarily true. An event that is impossible will have a zero probability. However, if an event is improbable, it still could be 100% possible. Concerning public health risks, because no information at all or only scanty information is available, not even preliminary probability estimates can be used; it is impossible to predict the next infectious disease to emerge, and it is impossible to predict the source or risk factors involved. It only is most possible that a new infectious disease will emerge some time somewhere.

Standard epidemiology for the effective analysis of emerging diseases at present lacks theory and tools to study the required complexity, being the central scientific problem of emerging diseases. New ways of configuring complex systems, fluid networks that capture the major 'drivers' through which most of the disease pathogens clearly move, are needed (Levins, 1995).

For practical reasons, as disease outbreaks occur, governments though will be exclusively judged on the basis on how they manage these incursions, rather than how they predicted whether they occur (Thiermann, 2001).

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