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Simon Rushton, Jeremy Youde

Emerging Infections

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David L. Heymann, Alison West
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EMERGING INFECTIONS
Threats to health and economic security

David L. Heymann & Alison West

Emerging infections provide a clear example of how infectious diseases cause a threat not only to human health but also to economic security. Emerging infections are caused by microbes that were not known previously to infect humans, or by microbes that were known to infect humans, but have begun to infect persons in a geographic area where they had previously not been seen. They cause human suffering, illness, and death; and they require medical care – sometimes costly because of the requirement for special procedures and protracted hospitalization. Their control may require culling of animals being raised commercially for food or other animal products, with loss of profit. And finally, emerging infections sometimes cause economic loss because of barriers to trade and travel when there is a perceived, often misguided, fear of their international spread.

A report published by the United States Institute of Medicine in 1992 first called attention to emerging infectious diseases as evidence that the fight against infectious diseases was far from won, despite great advances in the development of anti-infective drugs and vaccines (Lederberg et al. 1992). Since then, emerging infections have been identified at an average rate of one per year, sometimes in pandemic proportion when they spread throughout the world in a matter of weeks or months, placing millions of persons, or entire populations, at risk.

It is estimated that up to 70% or more of all emerging infections have a source in animals. Bats are particularly important carriers of infections that emerge in humans, and are often the source of emergence that leads to major outbreaks (Table 8.1).

Once an emergence has occurred there are three possible outcomes. Some emerging infections do not spread from person to person, and then disappear from human populations, but may reemerge when conditions are right. Others spread from human to human and cause an outbreak, then disappear when the outbreak is over, but may likewise appear again under the right conditions. Still others spread indefinitely, remaining in human populations as endemic infectious diseases for generations to come.

One of the most important recent emerging infections is AIDS, first identified in the early 1980s. AIDS is now an endemic disease, a human infection that continues to spread among humans, and from genetic study of the Human Immunodeficiency Virus (HIV) that causes AIDS, it is estimated that it actually emerged sometime during the late 19th or early 20th century from a nonhuman primate in the African rain forest, and then continued to spread from

Table 8.1 Breeches in the Species Barrier: Selected Emerging Infections since 1976

Infection	*Animal linked to transmission*	*Year infection first reported*
Ebola virus	Bats	1976
HIV-1	Primates	1981
E. coli 0157:H7	Cattle	1982
Borrelia burgdorferi	Rodents	1982
HIV-2	Primates	1986
Hendra virus	Bats	1994
BSE/vCJD	Cattle	1996
Australian lyssavirus	Bats	1996
Influenza A(H5N1)	Chickens	1997
Nipah virus	Bats	1999
SARS coronavirus	Palm civets	2003
Influenza (H1N1)	Swine	2009
MERS coronavirus	Possibly camel	2012
Influenza A(H7N9)	Chickens	2013

Source: Authors

human to human. Its emergence was likely caused by exposure of a hunter, or hunters, to the blood of an animal killed for food, and the virus was either able to easily transmit from human to human at the start, or it developed this capacity as it mutated during reproduction in the first humans infected. After its emergence, HIV continued to spread in human populations as a sexually transmitted infection. Sometime in the latter part of the 20th century, an infected human or humans carried the virus from rural areas where it had emerged and continued to spread at low levels, to urban areas where risky sexual behavior amplified the possibilities for it to spread, and to infect persons who then spread it from continent to continent as they traveled in an interconnected world.

Other recent emerging infections include Ebola, Marburg, variant Creutzfeldt-Jakob Disease (vCJD), Severe Acute Respiratory Syndrome (SARS), and avian and swine influenza. Each of these infections is thought to have infected humans by breeching the species barrier between animals and humans in whom they caused illness and were able to spread. Some of them, such as Ebola and Marburg, cause highly lethal outbreaks, then disappear from humans but reemerge at a later time when conditions, that are not yet clearly understood, are right. Others – such as SARS and swine influenza (influenza A – H1N1) – have the potential to cause a pandemic and spread throughout the world following major international airline routes.

This chapter will first examine the human health and economic consequences of emerging infections. It will then present in more detail the health and economic impact of two recent high profile emerging infection events – SARS and influenza. Finally it will briefly review measures that have been undertaken by countries to prevent the cross-border spread of emerging infections in the past, and describe the International Health Regulations (2005), the current global framework designed to prevent the international spread of emerging infections that are of international concern because of their potential to spread internationally and cause severe human and economic consequences.

The impact of emerging infections on humans and economies

Emerging infections cause human sickness and death, and they often pose a threat to economic security. During 2011, HIV was estimated to have caused 2.5 million new human infections and 1.7 million AIDS deaths worldwide, placing it high on the list of causes of human sickness and death (UNAIDS 2012). HIV is a chronic infection, and because of its long incubation period and the use of antiretroviral medicines to prolong life, persons infected with HIV accumulate in the population. By the end of 2011, therefore, it was estimated that 34 million persons were living with HIV infection, and that HIV infection had killed over 25 million people since AIDS was first identified in 1981. The sickness and death from HIV infection and AIDS have caused a direct and indirect negative economic impact, particularly in the poorest countries. The estimated direct costs in 2009 to achieve universal access to treatment and care for persons with HIV infection in developing countries was U.S. $7 billion, and reductions of 2%–4% in national GDP have been estimated across a range of African countries, mainly the result of lost human contribution to the work force because of sickness and death.

Variant Creutzfeldt-Jakob disease (vCJD) is a human infection that emerged in the United Kingdom (UK) in the mid-1990s. It spread to humans from cattle, or meat and other cattle products that were infected with the causative agent of Bovine Spongiform Encephalopathy (BSE), also known as Mad Cow Disease. vCJD does not spread from one human to another, and each human infection is thought to occur independently, either from infected cattle or products made from cattle. Since first being identified, 225 cases of vCJD have been reported from 12 countries, and each case has been fatal within a short period from onset. BSE was first identified in cattle in the UK during the 1980s. In order to rid cattle of infection, culling of herds with infected cattle was required. When it was understood that humans could be infected with BSE from cattle and cattle products in 1996, culling activity increased, and the economic loss in the UK during the following year was estimated to be U.S. $1.5 billion (Atkinson 1996). Trade of British beef and other cattle products was banned in many countries, markedly decreasing British exports, and adding greatly to the costs already associated with culling. In the 11 countries where BSE and vCJD had spread from the UK with cattle or bovine products, herds of cattle infected with BSE were culled at a considerable economic loss to each of these countries as well (Diack et al. 2012).

An extensive 2012 World Bank study estimated that economic losses from six major outbreaks of highly fatal emerging infections between 1997 and 2009 amounted to at least U.S. $80 billion. These infections include Nipah Virus (Malaysia), West Nile Fever (USA), SARS (Asia, Canada, others), Highly Pathogenic Avian Influenza (Asia, Europe), Bovine Spongiform Encephalopathy (US, UK), and Rift Valley Fever (Tanzania, Kenya, Somalia).

Case studies of emerging infectious diseases

Influenza

One infectious organism that is often able to spread easily from human to human after it emerges, or after it mutates, is the influenza virus (see Huang, chapter 7 in this volume). There are many different influenza viruses that live in aquatic birds, and these birds are thought to serve as the reservoir of human influenza infections. The influenza viruses in aquatic birds occasionally emerge in human populations, and while some of them are able to spread from human to human, others are not.

Some of those influenza viruses that spread from human to human eventually become endemic and cause seasonal influenza outbreaks each winter. A vaccine has been developed to protect against seasonal influenza, and it is provided to persons at risk of influenza each year before the influenza season. The vaccine is prepared from the influenza virus, but it becomes less effective as the virus mutates as it reproduces in humans. Because seasonal influenza viruses mutate frequently, there is a need for a change in influenza vaccine each year to match the mutated viruses so that the vaccine continues to protect humans against seasonal influenza. The Global Influenza Surveillance Network studies influenza viruses, and each year makes recommendations for the necessary changes in influenza vaccine 6 months before the influenza epidemic season, so that a new vaccine can be developed.

In addition to the influenza viruses that are circulating among humans and cause annual seasonal influenza outbreaks, other influenza viruses occasionally breech the species barrier between aquatic birds and animals such as pigs and poultry. Such was the case in 2009, when Mexico first reported human infections with the H1N1 (swine) influenza virus. This virus is thought to have undergone several different mutations in pigs and finally mutated in such a manner that it could then breech the species barrier between pigs and humans. Because it spread easily from human to human, it caused a major influenza outbreak in Mexico that then spread globally within weeks to cause a pandemic (Figure 8.1).

A total of 70,715 Mexicans were reported with confirmed H1N1 infection in the initial outbreak, of whom 1,316 (~ 5%) had died. By the end of 2009, more than 208 countries and territories had reported laboratory confirmed cases of pandemic influenza (H1N1) to WHO, and there had been at least 12,799 deaths.

Countries mobilized during 2009, and put into action their influenza pandemic plans after the World Health Organization (WHO) declared a public health emergency of international concern, and later WHO declared that H1N1 influenza had become pandemic. Though at no time did WHO recommend any decreases in pork trade and travel, there were major economic losses related to H1N1 in Mexico in both these sectors. They occurred because of an unwarranted perception among tourists and travel agencies that the risk of becoming infected with H1N1 was somehow greater in Mexico than elsewhere, even though the virus had spread throughout the world; and by a misunderstanding among pork markets that the pandemic was being amplified by infected pigs, despite the fact that it was being caused by human to human transmission, in which pigs no longer played a role.

Because of the resulting decrease in overseas visitors to Mexico, thought to be approximately 1 million, there was an estimated economic loss of approximately U.S. $2.8 billion. Because of unnecessary trade bans on Mexican pork products there was a major decrease in demand from the pork industry that contributed to a pork trade deficit of an estimated U.S. $27 million. In countries other than Mexico there were official recommendations, apparently based on this same misunderstanding, that likewise caused negative economic impact. In Egypt, for example, slaughter of pigs was ordered by the Egyptian Government early in the pandemic, even though the H1N1 virus had already been demonstrated to be highly transmissible from human to human, and despite the recommendation of the World Organization for Animal Health (OIE) that culling of pigs was not scientifically justifiable.

Countries around the world were affected as the H1N1 pandemic spread, and most economies suffered. In Spain, for example, the direct economic impact of illness from H1N1 influenza on health services utilization, and indirect costs from work absenteeism, has been estimated at €6,236 per hospitalized patient. In Canada, it is estimated that the cost of the increased patient load to hospitals caused by H1N1 between April and December 2009 was Canadian $200 million.

At the same time, other influenza viruses from aquatic birds continue to occasionally infect humans directly, or indirectly from intermediary animal populations that have been infected by these birds. The H5N1 avian influenza virus was first identified in Hong Kong as the cause of human illness in 1997. It was thought to have spread from migrating shorebirds to ducks, and

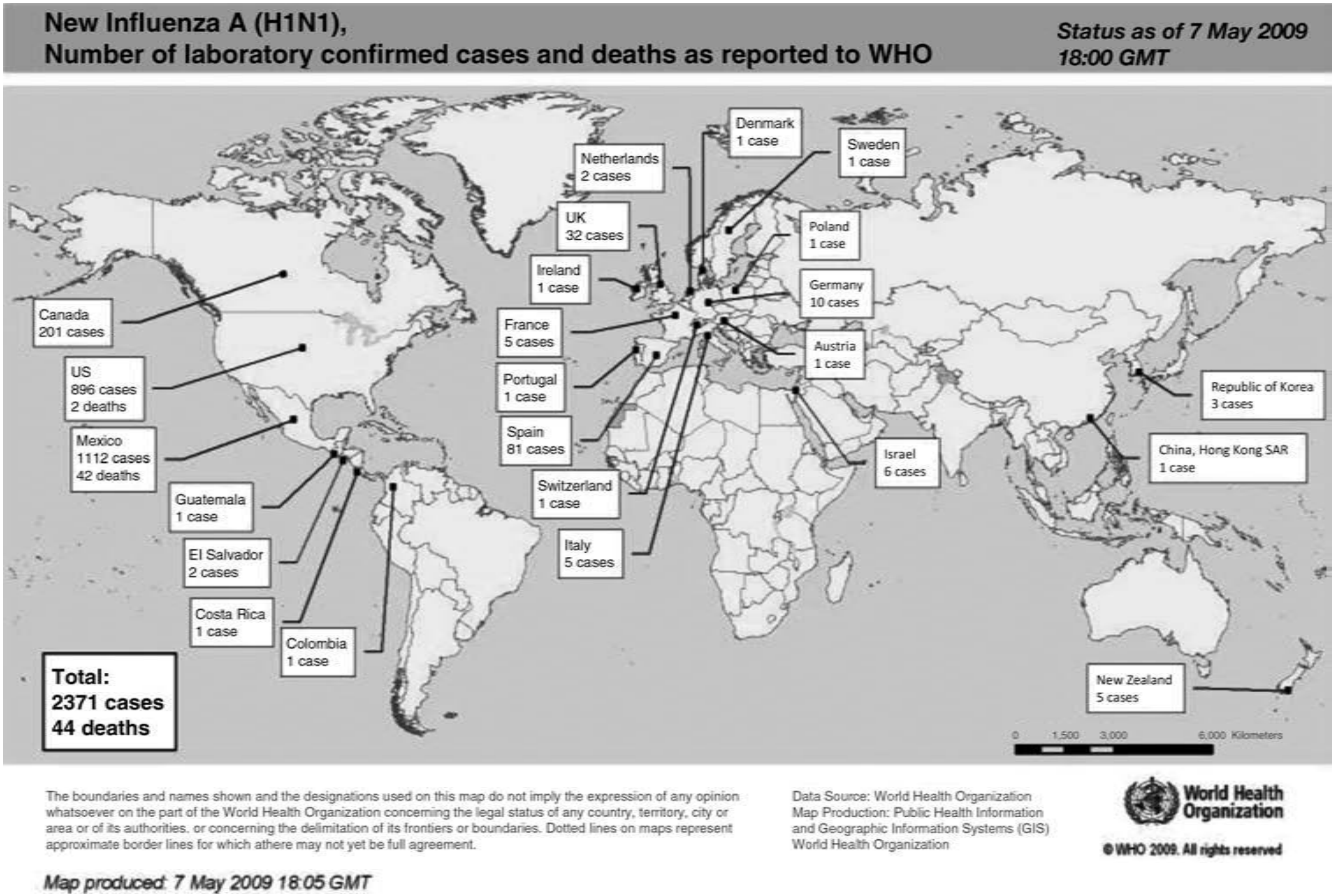


Figure 8.1 Rapid Spread of Influenza A (H1N1) after Emergence, 2009
Source: WHO.

then spread from ducks to chickens that were sold in live bird markets. Humans then became infected by exposure to infected chickens.

H5N1 has now spread to chickens in many parts of Asia, and the virus continues to cause occasional severe and fatal infections in humans when it breeches the animal/human species barrier, but it remains an endemic infection of poultry and does not transmit easily from person to person. The Global Influenza Surveillance Network continuously monitors H5N1, however, because like all influenza viruses, it has the potential to mutate into a form that could spread easily among humans. The highly fatal 1918 influenza pandemic is thought to have originated from an influenza virus that had spread from aquatic birds to pigs where it mutated in such a way that when it breached the species the animal/human species barrier it caused the highly lethal pandemic (Taubenberger & Morens 2006).

The World Bank predicts that a pandemic caused by a highly infectious and virulent influenza virus such as H5N1 could cost the world economy as much as U.S. $800 billion a year from direct patient costs, and indirect costs from lost lives, travel and trade (World Bank 2005). In order to prevent such a scenario related to the H5N1 influenza virus, attempts are being made to eliminate the H5N1 virus by culling entire flocks of infected poultry, mainly chickens. This precautionary measure, recommended by the World Health Organization and the Food and Agriculture Organization (FAO) in order to stop periodic emergence in humans, is causing lost revenue and poultry-replacement costs that have been estimated to be in the billions of U.S. dollars.

Severe acute respiratory infection (SARS)

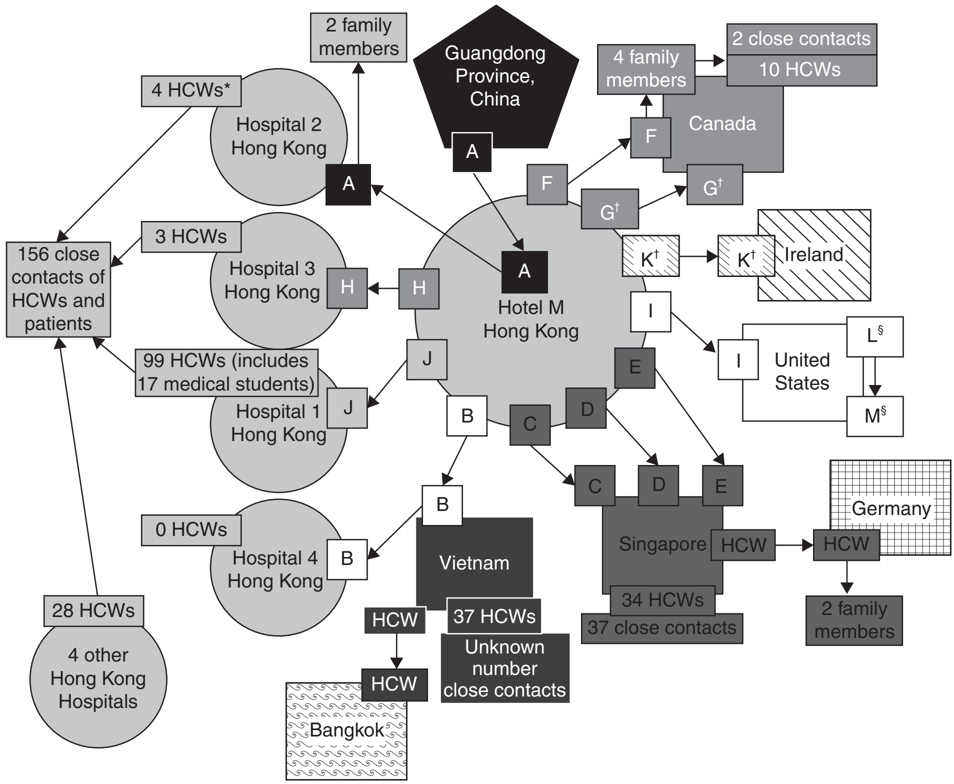
An outbreak caused by another breech in the animal/human species barrier occurred in the Guangdong Province of China in late 2002. The initial cases in the outbreak of SARS in China spread from human to human. Infected persons passed the infection to other family members and to health workers, and they in turn spread it to others in the community, causing an outbreak associated with severe illness and death.

In February 2003, when SARS was still unrecognized as a new and emerging infection in China, it crossed the border from the Guangdong Province to Hong Kong in a doctor who had been treating patients with SARS. He himself had become sick, and during a one-night stay in a Hong Kong hotel spread SARS to other hotel guests. Before they had any major symptoms, infected individuals travelled by plane to other Asian countries, North America, and Europe where they became sick and spread infection to others (Figure 8.2).

SARS had never before been seen in humans. There were thus no vaccines, medicines, or predetermined measures that could be used for its control. Because the virus continued to spread from human to human, there was concern that, like HIV, it would become an endemic infection, sustaining itself indefinitely in humans.

Precautionary measures to prevent international spread of the infection were immediately recommended by WHO – and there was an immediate decrease in international travel and tourism, most dramatic in Asian countries, and in Canada where major outbreaks had begun after tourists returned from Hong Kong where they had been infected by the infected medical doctor staying in the same hotel.

These precautionary measures caused a decrease in international air travel from geographic areas where outbreaks were occurring. Concern and panic ensued, however, among populations from other geographic areas as well – clearly demonstrated in a decrease in passenger movements through international airports. The precautionary prevention measures recommending that persons who were ill with SARS-like symptoms postpone travel resulted in a decrease of passengers who were ill, but many well passengers perceived the risk of travel as being great. This resulted



*Health-care workers.
†All guests except G and K stayed on the 9th floor of the hotel. Guest G stayed on the 14th floor, and Guest K stayed on the 11th floor.
§Guests L and M (spouses) were not at Hotel M during the same time as index Guest A but were at the hotel during the same times as Guests G, H, and I, who were ill during this period.

Figure 8.2 International Spread of SARS, 2003
Source: CDC/MMWR March 28, 2003 / 52(12): 241–248.

in a steady decrease in airline travel as in Hong Kong, where passenger movements at the international airport decreased soon after the outbreak was announced.

Figure 8.3 shows passenger movement through the Hong Kong Airport from March 16, 2003, the day after the announcement of the SARS outbreak, to July 2003 when the outbreak was declared over. Passenger movement decreased immediately after the epidemic was announced on March 15, continued to decrease after a travel advisory to postpone travel was made by WHO, but increased again beginning May 23 when WHO lifted the travel advisory.

Overall, Hong Kong International airport had had an approximate decrease of 70% in passenger movements in April 2003 compared with April 2002, and aircraft movements decreased by an estimated 30%. In April 2003, the number of flights canceled each day in and out of Hong Kong was around 164, representing more than 30% of all daily flights, and resulting in an estimated loss in landing fees in Hong Kong of a minimum of $3.5 million per day.

During this same period, income from restaurants, hotels, and retail sales decreased because of panic and misperception of the risk among the Hong Kong population that resulted in decreased

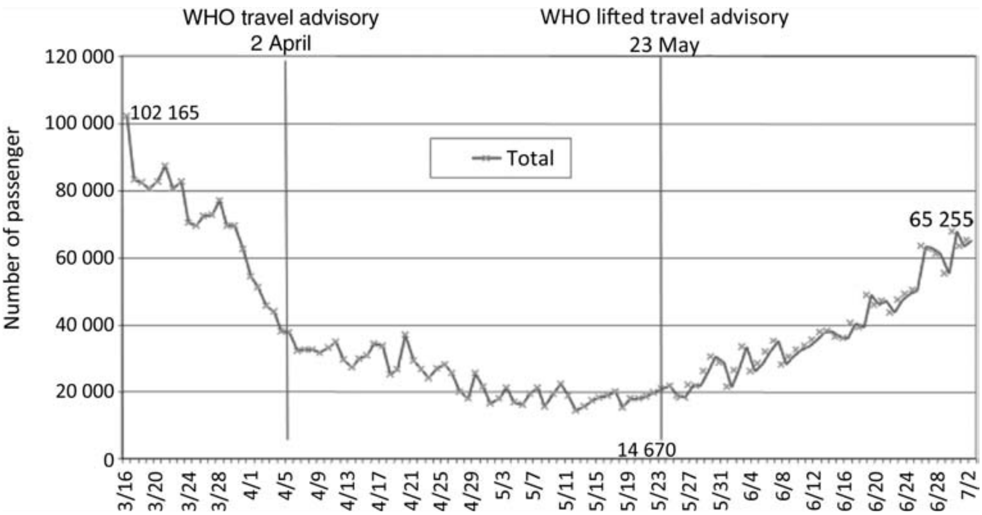


Figure 8.3 Passenger Movement, Hong Kong International Airport, March–July 2003
Source: Hong Kong International Airport.

consumer activity. Figure 8.4 provides clear examples of the decreases in economic activity that occurred.

The SARS outbreak ended in July 2003, and during the period 1 November 2002–7 August 2003, 8422 cases, of which 916 (11%) were fatal, were reported to WHO from 32 countries. The Asian Development Bank estimated the economic impact of SARS at approximately U.S. $18 billion in East Asia – around 0.6% of gross domestic product. But fortunately economic recovery was rapid once international spread had been stopped.

The International Health Regulations and international spread of infectious diseases

The International Health Regulations (IHR) are a global framework agreement of all Member States of the World Health Organization, and are designed to limit the international spread of public health emergencies, including emerging infections, with minimal interruption to travel and trade. They were first developed in 1969, and after the SARS outbreak in 2003 a process of updating and revision that had begun in 1996 was completed, broadening their disease coverage and setting up a process for more evidence-based recommendations for prevention and control. The concerns about the international spread of emerging infections that led to the development of the IHR in 1969 were not new (see Kamradt-Scott, chapter 16 in this volume). By the 14th century, governments clearly recognized the capacity for diseases to spread internationally. This was most clearly demonstrated in the city-state of Venice where quarantine measures were developed to attempt to stop the spread of bubonic plague. Ships arriving in the harbor of Venice were not permitted to dock for 40 days, and people at land borders were held in isolation, also for 40 days – one of the earliest well documented attempts to keep an infectious disease from crossing international borders.

By the mid-19th century, governments had become concerned that quarantine measures were not preventing the importation of another disease – cholera – and that the risk of plague remained. They recognized that better cooperation between countries was required in order to decrease the

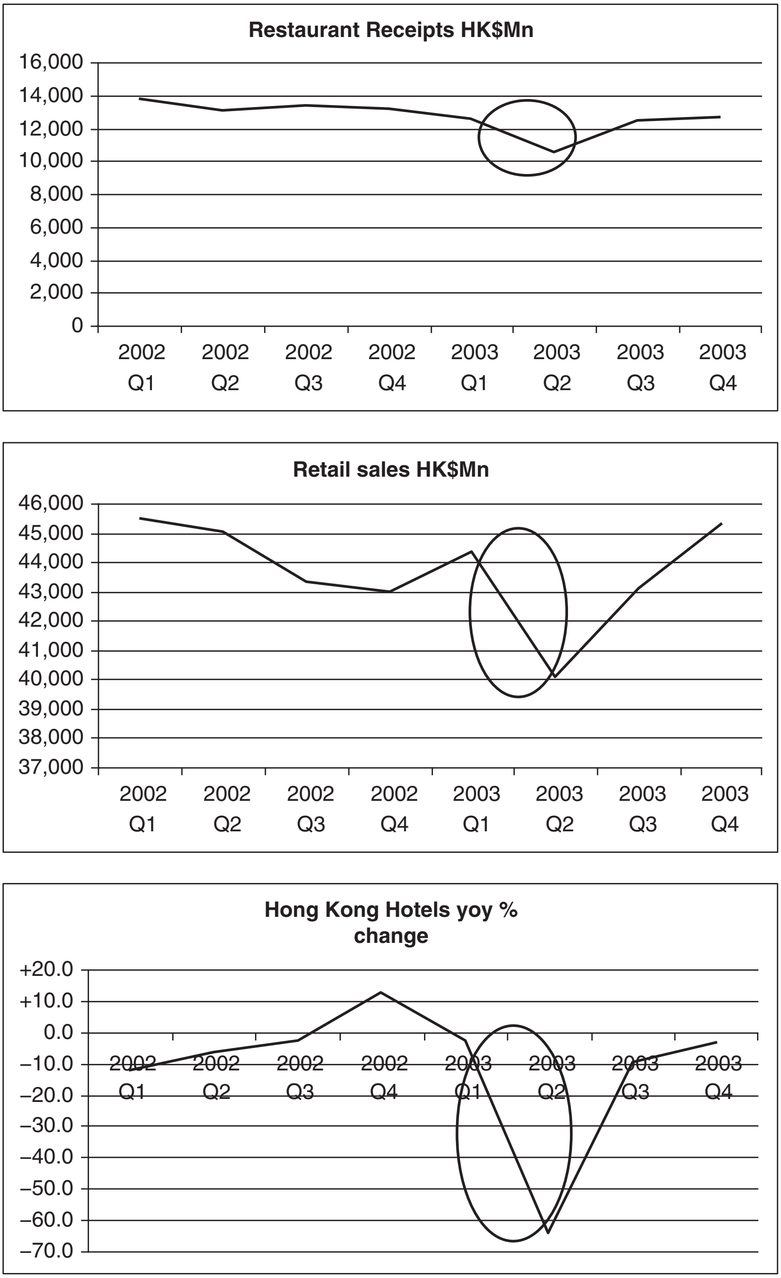


Figure 8.4 Revenue in Commercial Sector, Hong Kong, 2002–2003
Circles indicate period of SARS outbreak.
Source: Smith R, LSHTM.

risk of international spread of these diseases, and a series of international conventions were developed, aimed at stopping the spread of cholera and plague by applying certain measures at international borders.

During the 19th century, most international agreements to control the international spread of cholera and plague were among European countries. They began in 1851 in Paris, followed in 1892 by the first International Sanitary Convention that dealt with cholera. Five years later, at the 10th International Sanitary Conference, a similar convention was signed to prevent the spread of plague.

As communications technology developed, obligatory telegraphic notification of first cases of cholera and plague was begun among countries in the Americas, and these notifications soon included yellow fever as well. Because cholera and plague were often carried to the Americas by European immigrants, international agreements were broadened to include both Europe and the Americas.

During the early 20th century two major international sanitary bureaus were created to support the development of regional public health capacity against infectious diseases – one in the Washington for the Americas called the Pan American Sanitary Bureau (now called the Pan American Health Organization) and one in Paris for European countries, called the Office International d'Hygiène Publique. Cooperation between these two sanitary bureaus continued through the early part of the 20th century, and in 1951, after the creation of WHO, broad International Sanitary Regulations were developed as a means of fostering international cooperation in the control of cholera, plague, yellow fever, and smallpox.

In 1969, after over 20 years of implementation of the International Sanitary Regulations, WHO developed the International Health Regulations (IHR) – specifically aimed at better ensuring public health security with minimal interruption in travel and trade. In addition to requiring reporting of four infectious diseases – cholera, plague, yellow fever, and smallpox – the IHR were aimed at stopping the spread of these four diseases by the application of preestablished control measures at international borders. When a country reported one of these diseases, it triggered these standardized measures at border posts such as the requirement for yellow fever vaccination of passengers arriving from countries where yellow fever outbreaks had been reported. The international vaccination certificate, recognized by most countries, serves as official certification of vaccination under the IHR.

The IHR thus provided a legal framework for global surveillance and response, with the potential to decrease the world's vulnerability to four infectious diseases that were known to cross international borders. It soon became evident, however, that countries often reported late, or not at all, because of fear of stigmatization and economic repercussions. It was likewise understood by 1996 that the IHR did not meet the challenges caused by emerging infectious diseases and their rapid global transit, often crossing borders while still in the incubation period in humans, or silently in nonhuman hosts – insects, animals, and food and agriculture goods.

Therefore, from 1996 until 2005, the Member States of WHO undertook a process to examine and revise the IHR. The result – the IHR (2005) – provides a more up-to-date legal framework requiring reporting of any public health emergency of international concern (PHEIC) and the use of real-time evidence to recommend measures to stop their international spread. A PHEIC is defined as an extraordinary event that could spread internationally or might require a coordinated international response, and each newly identified outbreak is evaluated for its potential to become a PHEIC by the country in which it is occurring, even though reporting might legitimately come from elsewhere, using a decision tree instrument developed for this purpose.

Once a potential PHEIC is identified and reported to WHO by the country or countries concerned, the revised IHR require that an ad hoc Emergency Committee be set up to review the evidence available to WHO and conduct a risk assessment. A recommendation is then made to the WHO Director General as to whether or not the criteria for a PHEIC are met, and the Director General uses this recommendation, and other sources of information, to decide the course of action.

The Emergency Committee has met several times under the revised IHR, first when Influenza A (H1N1) was reported as a PHEIC by Mexico in 2009 when its risk assessment suggested that a pandemic would occur, after which the Director General declared a pandemic; and in 2012, 2013, and 2014 to conduct risk assessments of the newly emerging Middle East Respiratory Syndrome coronavirus (MERSCoV) that continues to sporadically infect humans, but has not been declared a global emergency by the Director General as of June 2014. WHO has continuously sought additional information about the MERSCoV from the countries in which is appears to be emerging in order that the Emergency Committee risk assessment can be more complete, but some of this information has not been forthcoming, and there is no enforcement mechanism within the revised IHR that can be used to obtain it.

Under the revised IHR countries are also required to notify WHO for even a single occurrence of a disease that would always threaten global public health security – smallpox, poliomyelitis caused by a wild-type poliovirus, human influenza caused by a new virus subtype, and SARS. In addition, there is a second list that includes diseases of documented – but not inevitable – international impact. An event involving a disease on this second list, which includes cholera, pneumonic plague, yellow fever, Ebola, and the other haemorrhagic fevers, still requires the use of the decision tree instrument to determine if it is a PHEIC. Thus, two safeguards create a baseline of public health security by requiring countries to respond, in designated ways, to well-known threats.

In contrast to the IHR of 1969 that only attempted to stop the spread of infections by action across international borders, the IHR (2005) have introduced a requirement that each country develop and maintain a set of core capacities for surveillance and response in order to rapidly detect, assess, notify, report, and contain the events covered by the regulations so that their potential for international spread and negative economic impact can be minimized. Countries are being monitored as to whether they have developed these core capacities by annual voluntary reports to the World Health Organization, based on a standardized self-assessment tool. Several countries have recently asked for an extension of the time period during which this core capacity strengthening must be accomplished, initially decided as 2007–2015. These extensions are being granted, but as for reporting of evidence required for risk assessment, there has been no enforcement mechanism established to ensure that core capacities are actually developed.

The IHR (2005) also require collective action by all WHO Member States in the event that an emerging or reemerging infectious disease begins to spread internationally, and the free-sharing of information pertaining to this threat. They thus provide a safety net against the international spread of emerging or reemerging infections, requiring collaboration between all countries to ensure the timely availability of surveillance information and technical resources that better guarantee international public health security.

Other international frameworks have also been developed to contain and curtail the international spread of emerging infections. Among them are the WHO Global Strategy for the Containment of Antimicrobial Resistance (World Health Organization 2001). Antimicrobial resistance – the acquired ability of microbes to resist treatment with antibiotics and other anti-infective drugs, is one of the most important emerging infectious disease problems of the 21st century. Resistant microbes can emerge anywhere where infections are present, including at the animal/human interface in shared human and animal ecosystems. Though not legally binding, this framework calls on countries to work across the human health, animal health, agricultural, and trade sectors to ensure more rational use of anti-infective drugs in order to limit the factors that accelerate the emergence and proliferation of anti-infective-drug-resistant microbes.

Conclusion

Emerging infectious diseases, most of which emerge at the animal/human interface, are clearly complex, dynamic, and constantly evolving. When they emerge, they have the potential for a major negative impact on economic security. At the same time however, efforts to prevent their international spread – either precautionary, evidence-based, or reactionary – can also have damaging economic repercussions because of measures such as culling and decreased travel and/or trade.

In 1969 the Member States of the World Health Organization put in place a global framework agreement, the International Health Regulations, in an attempt to ensure continued functioning of the global economy, international travel, and cross-border trade when three infectious diseases that had the potential to spread internationally were reported by the countries in which they were occurring. The IHR were based on the premise that international spread of these infectious diseases could be stopped by instituting predetermined measures at international border posts.

The International Health Regulations were revised and broadened in scope after the SARS outbreak in 2003 to include all public health emergencies of international concern, and the IHR are now based on the understanding that measures at international borders are not sufficient to decrease the risk of international spread of emerging infections – and that the best possible prevention is linked to rapid detection and response where and when infections emerge.

Under the revised IHR, WHO member states are now being monitored on the development of core capacities against a set of predetermined core capacities required to accomplish this. Monitoring is based on voluntary country reporting after having used a standardized self-assessment tool, but questions have arisen whether self-assessment is the best means of holding countries accountable and whether an external assessment is required.

Should country efforts to stop an emerging infection be unsuccessful, the revised IHR also provide a safety net for collective international action. An international Emergency Committee is now required under the IHR, and it is convened under the IHR to make recommendations to the Director General of WHO as to whether an event is a PHEIC, and if so what measures should be taken based on existing evidence. Limitations however, remain. Though the Emergency Committee requires best possible evidence for risk assessment, there is no enforcement mechanism that can be called into action if countries fail to collect and report the necessary information (see Hoffman, chapter 20 in this volume). This in fact, as for the SARS outbreak in 2003, requires additional international, sometimes political, pressure from the global community.

In summary, over the centuries the world has collectively made great advances in decreasing the risk of international spread of infectious diseases, including those that are emerging. International agreements have been regularly revised as better understanding of the dynamics of infectious, and emerging infectious diseases have been understood. Whereas in the past it was felt that international borders could effectively stop international spread when countries voluntarily reported, it is now understood that the best defense is rapid detection and response when and where infectious diseases occur or emerge.

At the same time, because the majority of emerging infections occur as breeches in the species barrier between animals and humans occur, there is growing understanding that the animal health and human health communities must work closer together under what is now called a "one health" framework. Challenges in working together are obvious: human concerns are about health and cost is often secondary, while animal health concerns are about making a profit on animals sold for food. The way forward includes understanding of the cost-effectives of intervening earlier at the animal health level and continuing to use, assess, and revise international agreements such as the IHR.

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