Institute
and Faculty
of Actuaries

Longevity Bulletin

From the Institute and Faculty of Actuaries

The pandemics edition

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Contents

1. Introduction by our President

With the ongoing outbreak of Ebola, as well as the recent MERS coronavirus and H7N9 avian flu outbreaks, the risk of emerging infectious disease and its potential to cause the next pandemic is a regular feature in the news. It is evident that the impacts of a pandemic could be very serious for society in general. However the insurance sector could also be significantly affected, not only because of extra claims but also because of the related economic reactions and operational risk issues. This issue of the Longevity Bulletin assesses the impact of pandemics from the various angles including risk modeling, epidemiology, health policy and technology.

I am proud to be given the opportunity to introduce the sixth issue of the Longevity Bulletin. I would like to thank all the contributors and authors for their thought-provoking and informative articles on the topic of global pandemics.

We hope that this issue will be read with interest by all those with a technical, professional or personal interest in longevity matters.

Best wishes,

Fiona Morrison
President, Institute and Faculty of Actuaries

2. Summary

Joseph Lu, Chair of the IFoA's Mortality Research Steering Committee

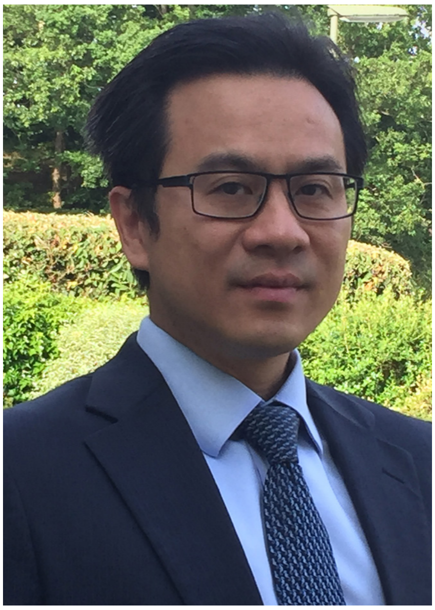
Despite dramatic advancement in medical sciences and healthcare in recent decades, we are still not immune to pandemics. A pandemic can be deadly and costly, as shown in the 1918 Spanish flu which killed more than 50 million people and cost the insurance sector about £13 billion worldwide in today's money.

At the time of writing this Longevity Bulletin, the World Health Organisation (WHO) warns of global outbreaks including Ebola (27,609 cases with 11,261 deaths), MERS-CoV (186 cases with 36 deaths), and Avian Influenza H7N9 (15 cases with 3 deaths) (WHO, 2015). With these outbreaks and increasing global travel, the risk of pandemic cannot be ignored. In this bulletin we have a selection of four articles written by experts from different disciplines to reflect current thinking on various aspects of the modelling, nature and mitigation of pandemic risk.

Pandemic risk modelling plays an important role in risk management and assessment of regulatory capital requirements in the insurance sector. Our modelling expert advocates a good understanding of current environment, drivers and process of deadly infection in modelling. This bulletin also offers ideas to deal with future uncertainty that might otherwise lead to severe operational challenges.

For illustration, we have included case studies on Spanish flu, HIV/AIDS and Ebola virus. They demonstrate the complexity of infectious diseases as they differ in origin, mode of transmission and impact on populations.

The UK government has policies and plans to deal with future pandemics. A range of interventions such as hygiene measures, social-distancing and vaccines are available to fight infection in the population. Recent advances in big data capability and social media data, when combined with genomics and spatial information, should provide notably quicker information flows to help minimise the spread of infection and facilitate faster treatments.



Despite these contingency plans, pandemic risk is being fuelled by global trends such as increased international travel, urbanisation and immune-deficiency due to disease or ageing. On the other hand, governments can fight contagions with vaccination, international surveillance and improved hygiene. These changes in the pandemic 'landscape' make the actuary's modelling task particularly challenging.

The actuarial community can add notable value by helping our stakeholders understand the risk and impact of pandemics, through modelling based on the latest scientific research.

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3. An actuarial perspective on pandemics

Dr Gordon Woo

Infectious disease pandemics such as Spanish flu, HIV/AIDS or Ebola have been a scourge on human society throughout recorded history. Fortunately, severe pandemics are rare, so their occurrence registers as an occasional spike in downward-trending mortality rates. The possibility of a large spike is significant for insurance risk management because of the premature death of significant numbers of insured lives, many of whom might be in middle age or younger. There would be substantial consequent volatility in cash flow.

In order to evaluate pandemic risk, a traditional actuarial approach would be to undertake a statistical analysis of past mortality experience. As with all extreme events, while it is possible to extrapolate from historical data, the reliability of the results is severely degraded by the paucity of historical events, and the evolution over time of both the human population and its interaction with the infectious disease environment.

To understand the scope of pandemic risk, the spectrum of possible future scenarios needs to be constructed based on the current human population and best scientific understanding of the infectious disease environment. This structured approach to dynamic modelling is more insightful for risk management than a purely statistical method, because of the sparse statistics of pandemics. Such a structured approach is highly computer-intensive and underpins the development of software for catastrophe insurance risk modelling over the past quarter century (Woo, 2011). Intrinsic to this approach is the incorporation into the modelling process of scientific knowledge and understanding. This extends to the inclusion of hypothetical scenarios that have no historical precedent, but yet are scientifically plausible. As an illustration of this foresight, the Risk Management Solutions (RMS) infectious disease model incorporated Ebola disaster scenarios years before the alarming 2014 Ebola crisis in West Africa (RMS, 2007).

The underlying mathematical framework for modelling the spread of an epidemic derives from equations of branching processes originally established formally by Kolmogorov and Dimitriev (1947). Amongst the population susceptible to an epidemic, some become infected. Of these, some recover and others are removed from the population through death. The acronym SIR modelling is used to reflect the dynamic shift between the Susceptible, Infected and Recovered population groups, as the contagion spreads, and eventually wanes.

The scale of pandemic risk

Each country has its own specific transmission variables associated with the standard of its public healthcare infrastructure, quarantining procedures, access to vaccines and medical interventions. Planning assumptions which inform pandemic response plans as well as clinical and non-clinical interventions are listed in Section 7 of this bulletin. Furthermore, the public threat of an epidemic is characterized by two key parameters: the case fatality rate and the basic reproductive number. The first of these is the proportion of those infected who do not survive. The second key parameter is the number of secondary infections generated by a primary infection.

A degree of negative correlation between these two threat parameters is suggested by an evolutionary argument: if a virus kills off an excessive number of hosts, then it will curtail its prospects for long-term survival. The avian flu virus H5N1 has a fatality rate, which might be as high as 60%, but is poorly transmissible between humans. Laboratory genetics research has been undertaken to assess what sequence of genetic mutations might turn H5N1 into an influenza virus transmissible through the air. However, without laboratory studies to force mutations, the time period for such random mutations to appear naturally through chance might be extremely long.

Of particular actuarial interest for life reinsurers are the extreme pandemic scenarios. How costly could one realistically be? A benchmark for a pandemic of insurance catastrophe proportions is the 1918 Spanish flu pandemic. The high case fatality rate of 2.5% is much higher than that of the other pandemics of the 20th century in 1957 and 1968, which were of the order of 0.1%. Far more people died of the influenza pandemic than in World War I itself (Taubenberger and Morens, 2006). In Europe, the excess mortality rate was about 1.1% of the population of 250 million (Ansart et al., 2009). By comparison, according to Eurostat data for HIV/AIDS, at its peak in the mid-1990s before there was effective treatment, about 0.01% of Europeans died from this disease of the immune system. In 2014, the European annual all-cause mortality rate was about 1%. The spectre of the European annual mortality rate doubling due to a very severe pandemic is an extremely challenging risk management scenario for the health sector, civic authorities and corporations, including life insurers. And it could be worse.

Conflicts and pandemics

Significantly for risk assessment, the two global disasters of World War I and the Spanish Flu epidemic were causally connected. The influenza was most likely brought to the Western Front by a cohort of 100,000 Chinese labourers who were despatched there by the Chinese government (Vergano, 2014) in the forlorn hope that, by assisting the Allies, China might be restored its north-eastern port city of Tsingtao, a former German colony. The 1918 pandemic is mistakenly called 'The Spanish Flu', because Spain was neutral during the World War I, and there was no news embargo on the death toll there. More accurately and informatively, the pandemic might be termed 'The Tsingtao Revenge'.

As illustrated by the Spanish Flu Case Study, standards of public health and medical advances today are far higher than in 1918, and actuaries may ponder the pathways by which a pandemic disaster of 1918 proportions could re-emerge. The linkage between political conflict and a global pandemic provides one clear route to disaster. Although the return period of a repeat of a 1918 pandemic loss is greater than 200 years (RMS, 2007), and hence does not have a dominant role in the calculation of capital requirements, there are other extreme scenarios, involving political instability, that might be used as realistic stress tests.

If an epidemic were to emerge in one of the numerous developing regions in a state of political unrest, civil strife or anarchy, the absence of disease surveillance and a fragile public health system could well allow the contagion to become established there and then spread abroad to other continents via refugees or general global travel with little constraint. Accordingly, a major global pandemic is a systemic actuarial risk, being coupled with supply chain breakdowns and business disruption, potentially aggravated by the destruction arising from political conflict.

The current civil war in Syria illustrates the public health crisis potential. The flow of Syrian refugees in Lebanon has led to a surge in communicable diseases in that country. Table 1 below shows the number of reported cases for 2011, 2012 and 2013 (Sharara and Kanj, 2014). (Leishmaniasis is a parasitic infection that leads to skin lesions resembling leprosy.) Given the overcrowding and lack of medical hygiene in refugee camps, it is evident that any outbreak of pandemic disease there would spread rapidly into the host community.

Economic Dislocation

In Europe, there are about six hospital beds per 1000 population, or 0.6%, most of which would be occupied for curing patients. This ratio is well below the mortality rate of the 1918 pandemic. So clearly the health services would be overwhelmed by a severe pandemic.

The impact on the workplace would inevitably be extremely disruptive. Apart from workers who are infected, others may not go to work for fear of becoming infected during their commute, or whilst at work itself. Parents may need to remain at home to look after children, whose schools have closed because of the high rate of contagion there. At absenteeism rates above 10%, work productivity drops off steeply; at 20% many businesses would be unable to function, and would suspend their operations. As a consequence, the global GDP might downturn by more than 5% (Cambridge Centre for Risk Studies, 2014), which would cause a sustained fall in financial assets. For life insurers, the mortality and morbidity claims resulting from an extreme pandemic would be the main concern, but there would also be a decline in asset values.

As evident from the Ebola crisis of 2014, there are severe operational challenges associated with the control of an emerging pandemic, which aggravate insurance loss. Where the death rate amongst health workers of an emerging pandemic is high, as it was for Ebola, staffing of field hospitals and medical centres may be fraught, unless the military become involved. The military excel above their civilian counterparts in diligent preparation for future major crises, and have a higher tolerance of personal physical risk. Their efforts were crucial in bringing the Ebola crisis under control. However, in future, if there happens to be an ongoing significant political conflict, the military support option may be curtailed. For example, there may be no military helicopters available to evacuate dangerously ill health workers; a resource constraint that would undermine their willingness to continue providing emergency healthcare. Financial austerity pressure on defence expenditure is highly susceptible to the law of unforeseen consequences: the security implications of defence cuts are very difficult to anticipate. One consequence is the erosion of European resilience against the ravages of a severe civil emergency, such as an extreme pandemic.

Table 1: Reported cases of communicable diseases per year between 2011 and 2013 in Lebanon

Disease	2011	2012	2013
Measles	9	9	1760
Leishmaniasis	5	2	1033
Hepatitis A	448	757	1551
Typhoid	362	426	407

The Ebola crisis of 2014 has passed, but it would have been far harder to manage had it occurred during the Sierra Leone civil war of the 1990s. In a world of political instability, the next pandemic may emerge in a conflict zone. The First World War and the great pandemic of 1918 were linked. The years leading up to the centenary of this pandemic should concentrate actuarial attention on prudent management of a catastrophe risk in an unstable world.

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Biography

Dr Gordon Woo is the chief architect of the RMS pandemic risk model, which was the first epidemiological model developed for the life insurance industry. He is the author of the two books, 'The Mathematics of Natural Catastrophes', (Imperial College Press, 1999), and 'Calculating Catastrophe' (Imperial College Press, 2011). Dr Woo graduated as the best mathematician of his year at Cambridge University, completed his PhD at MIT, and was a member of the Harvard Society of Fellows. He is a visiting professor at University College London.

4. Case study: 1918 Spanish flu

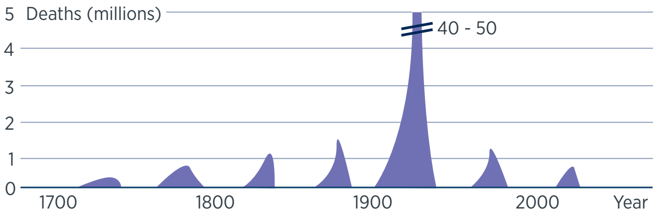
Influenza is a respiratory illness caused by several flu viruses.

The 1918 flu was a new strain that the world had not seen before, so few humans had any natural immunity. **This flu was one of the deadliest pandemics on record**, ultimately **claiming 50 million lives.** One third of the world's population may have been infected and death rates were 5 – 20 times higher than expected.

The virus was recently reconstructed by scientists at the Centre for Disease Control in the United States, studying remains of bodies preserved by the Alaskan permafrost. It is believed that a type of **H1N1 virus** was the cause of the pandemic – **variations of which still exist today in swine flu.**

Spanish flu relative to other pandemics

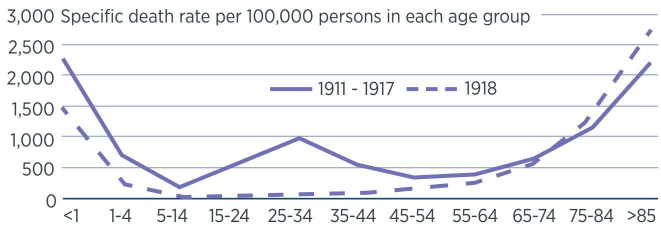
The 1918 Spanish flu pandemic was one of the largest public health catastrophes of the past century, causing **life insurance losses of nearly $100 million, which is comparable to nearly $20 billion today** (Insurance Journal, 2013). The graph on the right, which is not to scale, demonstrates the extreme nature of Spanish flu, relative to other pandemics over the last 300 years.



Potter (2001)

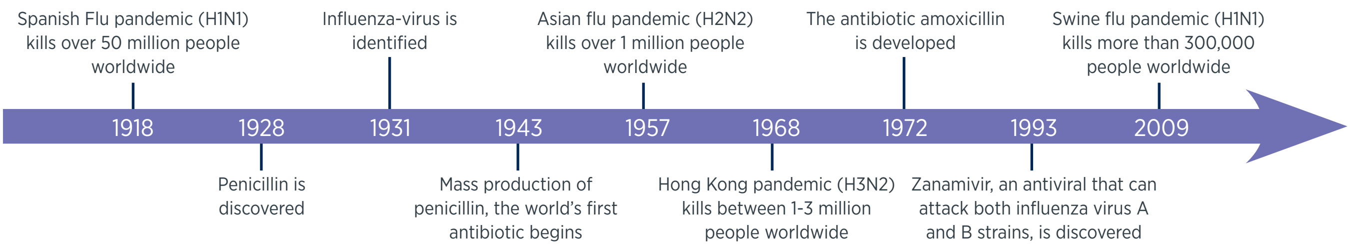
Mortality

Spanish flu is regarded as the benchmark against which others are being measured. It **killed more people in 24 weeks than AIDS has killed in 24 years.** Influenza usually kills the very young and very old (also referred to as U shape excess mortality). However, most of the deaths from the Spanish flu occurred in those **aged between 15 and 35**, resulting in excess deaths having an odd W-shape during this pandemic.



Taubenberger and Morens (2006)

Timeline of influenza pandemics and medical advances during the past century



The rate of medical development since 1918 has been huge and the medical infrastructure is better able to cope with a pandemic. Experts do not know what the impact of a new pandemic could be, but there is a general agreement that the 1918 scenario is very extreme.

The likelihood that a similar scenario to Spanish flu will occur in the future is estimated to be less than 1 in 400. As yet, there is no cure against the mutated virus and **the virus would probably travel much more quickly around the world today with the greatly increased amount of air travel.**

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5. An epidemiological perspective on pandemics

Dr Alison Martin

The previous article referred to the 1918 Spanish flu as the benchmark against which others are being measured. Together with the Black Death of the 14th century, each of these pandemics caused over 50 million deaths worldwide, yet they share few other common features.

This article explores some of the characteristics of infectious diseases that are capable of global outbreaks, and the factors that increase and decrease the risk of a pandemic.

Types of micro-organisms that can cause pandemics

Widespread infections can be caused by bacteria, viruses or other micro-organisms including parasites. Some only infect humans, others use other animals as hosts as well as humans. Table 1 summarises the characteristics of some infections capable of causing a pandemic.

Pandemics are especially likely where there is human-to-human transmission but where animals also carry the infection, meaning eradication is more difficult.

Table 1. Types of infectious diseases with pandemic potential

	Bacteria	Viruses	Parasites
Only survive in humans, transmission human-to-human	Cholera Meningococcal meningitis Tuberculosis (pulmonary)	Hepatitis B Hepatitis C HIV/AIDS Measles Poliomyelitis Smallpox	
Use other animal vectors as host, transmission vector-to-human and human-to-human	Tuberculosis (bovine)	Ebola Influenza Middle East Respiratory Syndrome Coronavirus (MERS) Severe Acute Respiratory Syndrome (SARS)	
Use other animal vectors as host, transmission vector-to-human	Plague		Malaria

Routes of transmission

Transmission of infectious diseases can be by direct or indirect contact between people, with or without animal vectors. The main routes of transmission for pandemic-risk infections are shown in Table 2. Droplet or airborne dissemination is one of the most effective ways of spreading an infection widely and rapidly. This is one reason why influenza has caused so many pandemics, while Ebola has been more easily contained within one region of the world. However, as illustrated by the Ebola Case Study, the virus has now spread to dense urban areas, where control is harder to achieve.

Table 2. Routes of transmission of diseases with pandemic potential

Route of transmission, with typical circumstances	Examples of infections transmitted this way
Contact with blood: • intravenous drug use • blood transfusion • needlestick injuries	Hepatitis B and C HIV
Contact with other body fluids: • nursing the sick • laying out bodies of the dead • touching contaminated surfaces	Ebola Hepatitis B Influenza Measles SARS Smallpox
Sexual contact	Ebola (possibly) Hepatitis B (sometimes C) HIV
Mother to child: • during pregnancy or childbirth • breastfeeding	Hepatitis B and C HIV
Droplet spread: • cough • sneeze	Influenza Measles Meningococcal meningitis MERS (possibly) Plague (pneumonic form) SARS Smallpox Tuberculosis (active pulmonary disease)
Food or water contamination: • drinking water • consumption of contaminated food	Cholera Poliomyelitis
Animal vectors: • insect bites • contact with infected animal • consumption of infected meat	Ebola (initial cases) Influenza (initial pandemic strain cases) Malaria MERS (possibly) Plague

Prevention and treatment

Much of the decrease in cases and mortality from infectious disease in developed countries has come from improved sanitation, reduced overcrowding, and better resilience of the well-nourished population. Vaccination has also had a substantial impact, in particular against smallpox, polio and measles. Vector control with insecticides and use of mosquito nets can prevent transmission of malaria. An important aspect in prevention and treatment is also the guidance and preparedness plans, both of which are discussed in the next article.

Bacteria and parasites are relatively easy to control with antibiotics. Equivalent treatment of viruses has been more difficult, but antiviral drugs have been very successful in controlling HIV infection and have contributed to the remarkable fall in mortality since 1994 as shown by the HIV/AIDS Case Study in this bulletin.

Unfortunately, micro-organisms rapidly develop resistance to antibiotics and antiviral drugs, especially where these are used at low concentrations that kill the susceptible strains but allow those with natural resistance to flourish. This occurs from inappropriate prescription of antibiotics and intensive farming. Antimicrobial resistance is of particular concern in the following pandemic-risk diseases:

- Tuberculosis: multidrug resistance affected 480,000 people globally in 2013, and 9-13% of these are thought to have extensively-resistant strains (WHO Tuberculosis, 2015)
- HIV: Highly Active Antiretroviral Therapy (HAART), combination treatment with 3 drugs, has been required to reduce resistance.
- Influenza: in 2011 in Europe, 3% of seasonal influenza isolates were resistant to the drug oseltamivir (ECDC 2012).
- Malaria: antimicrobial resistance to traditional drugs is widespread and is increasing to newer drugs (WHO Malaria, 2015).

Factors affecting the risk of an outbreak becoming a pandemic

Changes in where and how we live have had a substantial effect on the risk of pandemics and their impact on mortality. Some changes have increased the risk, others have reduced it, and some can do both, depending on the circumstances, and these are summarised in Table 3.

Table 3. Factors increasing or decreasing the risk of pandemics

Factor increasing the risk of pandemic	Examples	Factor decreasing the risk of pandemic	Examples
International travel and tourism	Faster spread of infections with human-to-human contact, e.g. influenza, SARS. Migrants may carry chronic infections, e.g. tuberculosis, HIV. Increased exposure to "exotic" infections from returning travellers, e.g. new viral haemorrhagic fevers. Overcrowding, such as on pilgrimages increases risk of meningococcal meningitis	Vaccination	Can keep immunity above the 80% threshold required to prevent transmission of infection, e.g. measles, hepatitis B. Can eradicate infections with only humans as hosts, e.g. smallpox, polio.
International trade	Can transmit food-borne infections, e.g. cholera. Animal vectors may be transported with cargo, e.g. plague, malaria.	International surveillance	Facilitates early detection and control of outbreaks before they become pandemics, e.g. influenza.
Industrialisation	Overcrowding in urban slums and poverty increases risk, e.g. cholera, tuberculosis.	Improved sanitation	Reduces the risk of water-borne infections, e.g. cholera, polio.
Antigen change	Rapidly evolving variants of antigens mean vaccines are difficult to develop or quickly out of date, e.g. influenza, HIV.	Antigen change	Virulence of previous pandemic strains can decrease over time, so risk of severe infection and mortality may fall, e.g. H1N1 influenza, plague.

Factor increasing the risk of pandemic	Examples	Factor decreasing the risk of pandemic	Examples
Ageing population	Elderly have comorbidity and reduced immunity so at greater risk of severe illness, e.g. seasonal influenza, MERS.	Ageing population	Residual or partial immunity from previous exposure can protect the elderly from new variants of established infections, e.g. H1N1 influenza. Older people may be at lower risk of immune system over-reaction e.g. cytokine storm with H5N1 influenza
Impaired immunity	Malnutrition and HIV increase the risk and severity of other infections e.g. tuberculosis, hepatitis B/C, cholera.	Improved general health and nutrition	Increases resilience to all disease, so risk and severity of infection are reduced e.g. meningococcal meningitis.
Emerging infections	New infections mean no existing immunity so everyone is vulnerable, e.g. smallpox in North America (1600s), Ebola (1976), HIV (1980s), SARS (2002), MERS (2012).	Rapid and affordable molecular typing of infective strains	Allows rapid identification of new strains, confirms outbreaks of infection, and facilitates development of new vaccines, e.g. identification of circulating strains of influenza.
Climate change	Increasing global temperature by 2-3°C could increase the number of people at risk of malaria by 3-5% (or several hundred million) (WHO, 2003) e.g. outbreak in Greece in 2011. Warmer conditions favour water-borne bacterial infections, e.g. cholera. Climate change alters farming practices so can change vector habitats, e.g. Dengue and West Nile virus are appearing in new countries.	Climate change	Drought can destroy humid environment required for insect vectors, e.g. malaria.
Conflict and natural disasters	Mass migration causes overcrowding and impaired sanitation, which increases the risk and severity of infections e.g. cholera, measles Terrorism may involve deliberate release of infection e.g. smallpox, SARS.		
Farming practices and food provision	Intensive farming encourages new animal-borne infections from crowding, e.g. influenza, or irrigation, e.g. malaria. Close habitation with farm animals increases mixing of viruses e.g. chickens, pigs and humans increases risk of new strain of pandemic influenza. Consumption of bush meat in Africa facilitates transmission of animal-borne virus, e.g. Ebola. Inappropriate farming methods can spread new pathogens e.g. human variant Creutzfeld-Jakob disease.		

What is the greatest threat for future pandemics?

The greatest risk of new pandemics is likely to come from a new strain of an existing virus, or an entirely new type of viral infection, that is transmitted by droplet spread from human to human. These conditions are most likely where humans and animals cohabit in economically disadvantaged locations where health services are sparse and baseline health is poor. Outbreaks of pandemic influenza in Asia and Ebola in Africa have shown how easily some or all these criteria can be met. Our best chance to minimise the harm from such a pandemic is to have effective surveillance systems to actively look for such infections, and for the international community to respond rapidly and effectively to emerging threats.

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Biography

Dr Alison Martin has experience as a junior hospital doctor working in general medicine, nephrology, medical oncology, cardiology, general surgery and urology. However, most of her career has been spent working in the field of evidence-based medicine for organisations including Drug and Therapeutics Bulletin, the British Medical Journal (BMJ) Group, Matrix Knowledge Group and Evidera. At the BMJ Group she was a Senior Clinical Editor on evidence-based publications for clinicians and other healthcare staff and researchers, including BMJ Clinical Evidence, BMJ Best Practice and BMJ Action Sets. Alison is now Principal Medical Writer at Crystallise Ltd.

6. Case study: HIV/AIDS

Acquired immune deficiency syndrome (AIDS) is a disease of the immune system caused by human immunodeficiency virus (HIV).

1900s

There is evidence that the origin of HIV is the **Simian Immunodeficiency Virus** (SIV), and scientists believe that the virus jumped to humans in the early 1900s. The virus spread when a bush meat hunter in Congo killed and ate an **infected ape or chimpanzee.** In early the 1980s, still very little was known about transmission and public **anxiety and fear** continued to grow.

Death rate in 25-44 year olds

In the early 1980s, the biggest killers of 25–44 old year men were **accidents** (about 36 per 100,000), **cancer** (about 25 per 100,000) and **homicide** (about 15 per 100,000). By 1994, deaths from **HIV/AIDS had overtaken deaths from all the other causes.** However, by the turn of the century, deaths from AIDS had taken a very sharp downturn.

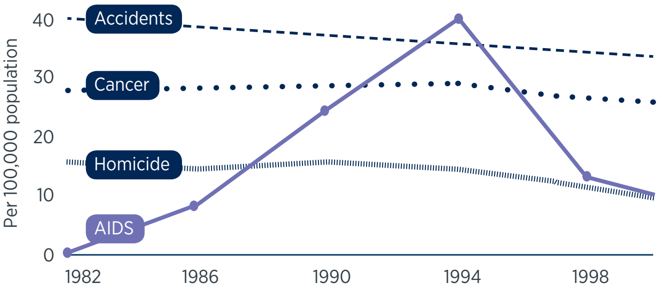
The remarkable fall in mortality since 1994 reflects the new drug therapies that have become available over the past two decades.

Trends, 1981 - 2014

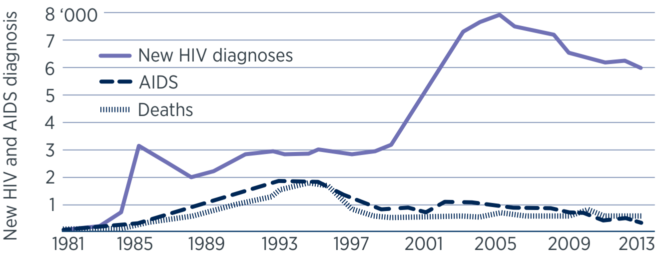
The UK has a relatively small HIV and AIDS epidemic in comparison with some parts of the world. **An estimated 98,400 people in the UK – or around 1.5 per 1000 of the UK population – are currently living with HIV**. Although HIV and AIDS receive less attention from the media in the UK than they did during the early years of the UK AIDS epidemic, it's far from an issue of the past. In fact, the epidemic has expanded, with the annual number of **new HIV diagnoses nearly tripling between 1996 and 2005.**

1987

In 1987 Zidovudine (AZT) became the first drug to be approved by the US FDA (Food and Drug Administration) for the purpose of prolonging life of AIDS patients. The gain from AZT was very small as it only **increased life between two to three years.** However, since then many other retroviral drugs have had a much more significant effect on life expectancy and on quality of life for those with AIDS and HIV.

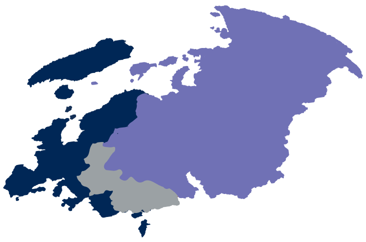


Condon and Sinha (2008)

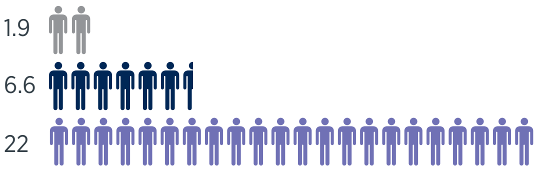


Public Health England (2014)

HIV in Europe



New HIV cases in the WHO European Region.
Average number of new HIV cases per 100,000 people:



In 2013 there were
80% more
new HIV cases compared to 2004. Alarmingly, around **half of those** people do not know that they are infected.

World Health Organization (2013), (2015)

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7. A policy perspective on pandemics

Dr Chloe Sellwood

Many people will be familiar with the term and popular concept of an apocalypse through recent films such as *I am Legend* (2007), *World War Z* (2013), *Contagion* (2011) and *Dawn of the Planet of the Apes* (2014) where an infectious disease rapidly spreads around the world wiping out virtually all of humanity. However this is not true for all pandemics and while this article will focus on influenza when considering the policymakers' perspective of pandemic preparedness and response, many of the public health impacts of other infectious agents are common and consequently plans and policies for intervention can encompass common elements.

Background to influenza pandemics

Influenza is a virus that causes many deaths in thousands of people across the globe every year. The natural reservoir for influenza is wild water birds where the virus is endemic. However it can readily infect and cause illness in a wide range of animal populations including domestic poultry, swine and humans. With increasing close cohabitation of people with their animals there are ever more opportunities for novel viruses to cross species barriers while increasingly intensive farming practices and globalisation present more opportunities for a virus to rapidly spread in populations and cause epidemics or pandemics of disease (Table 1).

Table 1: The Spread of Diseases

Endemic: An illness or infection that is persistently present in a certain a population.	**Epidemic:** The sudden surge in cases above baseline levels of an infectious disease in a given population within a short period of time, usually two weeks or less. Epidemic is derived from Greek meaning 'upon people'.	**Pandemic:** An epidemic of infectious disease that has spread through populations, for example across continents or worldwide. Pandemic is derived from the Greek pan meaning 'all' and demos meaning 'people'.

Influenza pandemics have been recorded throughout history, however as previously mentioned in this bulletin, the best known pandemic is the 1918 Spanish flu pandemic. Pandemic preparedness is informed by planning assumptions developed from information on previous events such as those shown in Table 2. In the UK, the pandemics of the 20th century informed the planning assumptions that guided the early response to the 2009/10 pandemic.

Table 2: Pandemics in the 20th Century

Year	Common name	Origin	Global mortality	Waves	Ages/ groups affected
1918	Spanish flu	USA/ China	20-40 million	Three	Very young, older people, and 20-40 year olds
1957	Asian flu	China	1 million (mainly older people)	Two	School age children
1968	Hong Kong flu	China	1-3 million	One	Older people relatively protected
2009	Swine flu	Americas	300,000	Two to three	School age children, pregnant women and morbidly obese at increased risk

Outbreaks of avian influenza A/H5N1 in human populations in Hong Kong in 1997 (18 cases, including six fatalities) and subsequently across south east Asia from 2003 to 1 May 2015 (840 cases including 447 fatalities) as well as the SARS outbreak in 2003 (Parashar and Anderson, 2004) gave global impetus to pandemic influenza preparedness activity, led by the World Health Organization (WHO). When the first pandemic of the 21st century occurred in 2009, many countries had considered issues that subsequently presented during the pandemic. This pandemic has typically been described as mild, and there has been an equal amount of criticism for over-reaction (because planning assumptions relied on knowledge from the events in the 20th century) as well as commendation for a well-prepared and managed response (because we had planned based on events in the 20th century) (Hine, 2010).

In June 2013 the WHO published revised pandemic influenza guidance. This moved away from the previous six pandemic phases, and instead uses a risk-based approach represented as a continuum of global phases (inter-pandemic, alert, pandemic and transition) that describe the spread of a new influenza subtype, taking account of the disease it causes, around the world. It recognises the importance of national, regional and local plans for pandemic influenza that can be activated within the WHO framework (WHO, 2013).

UK pandemic influenza preparedness and response

Since the 2009/10 pandemic, the UK government continues to recognise pandemic influenza as one of the most substantial risks to the UK (Figure 1) and consequently activity continues across UK organisations to prepare for a future event.

The Department of Health (DH) is the lead government department for UK pandemic preparedness and response. Many lessons were identified following the 2009/10 pandemic, and in 2011 DH issued new guidance that reflected revised planning assumptions, key changes in the description of pandemic phases, and a de-coupling from the previously rigorous link into global activities during a response to ensure a more precautionary, proportionate and flexible UK response (DH, 2011). The key planning assumptions used to inform pandemic response planning are listed in Table 3, while the revised UK pandemic phases are shown in Table 4.

Figure 1. UK National Risk Register of Civil Emergencies (2015)

Risk of terrorist and other malicious attacks

Overall relative impact score	Low	Medium low	Medium	Medium high	High
5		Catastrophic terrorist attacks			
4					
3		Cyber at-tacks: Infrastructure	Terrorist attacks on infrastructure Smaller-scale CBR terrorist attacks	Terrorist attacks on crowded places	Terrorist attacks on transport systems
3					
1					Cyber attacks: data confidenti-ality

Relative plausibility of occurring in the next five years

Other Risks

Overall relative impact score	Between 1 in 20,000 and 1 in 2,000	Between 1 in 2,000 and 1 in 200	Between 1 in 200 and 1 in 20	Between 1 in 20 and 1 in 2	Greater than 1 in 2
5				Pandemic influenza	
4			Coastal flooding Widespread electricity failure		
3		Major transport accidents Major industrial accidents	Effusive volcanic eruption Emerging infectious disease Inland flooding	Severe space weather Low tem-peratures and heavy snow Heatwaves Poor air quality events	
2			Animal diseases Drought	Explosive volcanic eruption	
1			Disruptive industrial action		

Relative likelihood of occurring in the next five years

Table 3: UK pandemic planning assumptions – adopted from the UK Influenza Pandemic Preparedness Strategy (2011)

- influenza pandemics are intrinsically unpredictable, plans should therefore be flexible and adaptable for a wide range of scenarios
- during a pandemic, the assumptions on which to base the response will be updated in the light of emerging evidence about the range of likely scenarios at the time
- even pandemics with only mild or moderate impact are likely to put considerable pressure on services and the experience in local areas could be much more severe
- an influenza pandemic could emerge at anytime, anywhere in the world (including in the UK); it could emerge at any time of the year and regardless of where or when it emerges, it is likely to reach the UK very quickly
- it will not be possible to stop the spread of (or eradicate) the virus either in the country of origin or in the UK as it will spread too rapidly and too widely
- from arrival in the UK, it will probably be a further one to two weeks until sporadic cases and small clusters of disease are occurring across the country
- initially, UK pandemic influenza activity may last for three to five months, depending on the season, and there may be subsequent substantial activity weeks or months apart
- it is likely that infected people will exhibit a wide spectrum of illness, ranging from minor symptoms to pneumonia and death; most who recover will return to normal activity within 7 – 10 days
- all ages are likely to be affected but those with certain underlying medical conditions, pregnant women, children and otherwise fit younger adults could be at relatively greater risk; the exact pattern will only become apparent as the pandemic progresses
- the UK continues to maintain stockpiles and distribution arrangements for antiviral medicines and antibiotics, as well as personal protective equipment (PPE), sufficient for a widespread and severe pandemic
- up to 50% of the population could experience symptoms of pandemic influenza during one or more pandemic waves lasting 15 weeks, although the nature and severity of the symptoms would vary from person to person
- up to 30% of symptomatic patients may require assessment and treatment in usual pathways of primary care, assuming the majority of symptomatic cases do not require direct assistance from healthcare professionals
- 1 to 4% of symptomatic patients will require hospital care, depending on how severe the illness is, and there is likely to be increased demand for intensive care services
- if no effective treatment was available, up to 2.5% of those with symptoms could die as a result of influenza in a severe pandemic, however local planners should plan for 210-315,000 excess deaths over the duration of a pandemic.

Table 4: UK pandemic response phases - adapted from the UK Influenza Pandemic Preparedness Strategy (2011)

Phase	Activity
Detect Upon declaration of a WHO Public Health Emergency of International Concern	• Intelligence gathering from countries already affected • Enhanced surveillance within the UK • Developing diagnostics specific to the new virus • Information and communication to the public and professionals
Assess Upon identification of the novel influenza virus in UK patients	• Collecting and analysing clinical and epidemiological information on early cases, to inform early estimates of UK impact and severity • Reducing the risk of transmission and infection within the local community by case finding, case isolation, case treatment
Treat Upon evidence of sustained community transmission of the virus	• Treating individual cases and population treatment (via the National Pandemic Flu Service[2] if necessary) • Enhancing the health response to deal with increasing numbers of cases • Considering enhancing public health measures to disrupt local transmission of the virus • Depending upon the development of the pandemic, preparing for targeted vaccinations as the vaccine becomes available

[2] The NPFS is a web and telephone based service that can be used to assess potential influenza patients, in a rapid and safe manner via a standard clinical algorithm, for antiviral treatment

Escalate When demands for services start to exceed the available capacity	• Escalating surge management arrangements in health and other sectors • Prioritising and triage of service delivery with aim to maintain essential services • Resiliency measures, encompassing robust contingency plans • Considering response de-escalation if the situation is judged to have improved sufficiently
Recover When influenza activity is either significantly reduced compared to the peak or when the activity is considered to be within acceptable parameters	• Normalisation of services, perhaps to a 'new' normal • Restoring business as usual services, including catching-up e.g. rescheduling routine operations • Sharing lessons identified through post-incident review and debrief • Taking steps to address staff exhaustion • Planning and preparing for a resurgence of activity, including activities carried out in the DETECT phase • Continuing to consider targeted vaccination, when available • Preparing for post-pandemic seasonal influenza

In addition to the revised planning assumptions and a rethink of pandemic phases that underpins national, regional and local pandemic planning and response, there have also been major changes to the NHS and wider resilience preparedness and response landscape since the 2009/10 pandemic following the change of government in the UK in 2010 (see Table 5). These offer challenges as well as opportunities for a different type of response to a future pandemic that policy makers must consider.

Table 5: Key changes to the NHS and wider resilience landscape in England since 2010

Dis-establishment of Strategic Health Authorities (SHAs), Primary Care Trusts (PCTs) and the Health Protection Agency (HPA) – key responding organisations during 2009/10 with significant command and control responsibilities
Establishment of Clinical Commissioning Groups (CCGs), NHS England and Public Health England (PHE) – greater localisation of healthcare commissioning (CCGs) coupled with improved opportunities for response arrangement consistency across the country (NHS England)
Establishment of Local Health Resilience Partnerships – new multi-health organisation committees responsible for the oversight of health emergency preparedness and resilience
Relocation of Directors of Public Health (DsPH) from the NHS into local authorities – improved integration in the wider aspects of local population health and well-being

Interventions

A range of interventions are available for pandemic influenza, including clinical (e.g. vaccination and anti-microbial treatment) and non-clinical (e.g. social distancing and hand/respiratory hygiene) measures. Policy makers must select interventions that are appropriate to the scenario, while considering the likelihood of acceptance and effectiveness in their population, as well as associated cost and benefits. Additionally, some interventions are more effective early in a response – such as quarantine or self-isolation before a pathogen becomes widespread, while others may be beneficial throughout – such as hand washing. Some, such as a specific vaccine, may not become available for many months (Van Tam and Sellwood, 2012).

In the UK, specific national workstreams are considering how to ensure symptomatic members of the public can rapidly access antivirals in a manner that is reliable and acceptable, as well as how a pandemic-specific vaccination campaign may be delivered to the population. Work is also underway to consider the management and distribution of stockpiles of items of personal protective equipment (PPE) that the NHS would need when caring for an increased number of respiratory patients with influenza. This work is led by NHS England, in partnership with PHE and DH, and is building upon lessons identified in 2009/10.

Other infectious disease

However it isn't all about influenza. Another respiratory infection could easily emerge or re-emerge and cause human disease (Nguyen-Van-Tam and Sellwood, 2013). In recent years, MERS-CoV (a virus similar to SARS) has caused many cases and fatalities across the Middle East, and as yet the reservoir of this virus remains unconfirmed. In May 2015, the largest outbreak of this virus outside of the Middle East started in South Korea, and to date (13 July 2015) almost 186 cases have been identified, including over 36 fatalities (WHO - MERS-CoV, 2015). Although this development has not changed global risk assessment, it does serve to illustrate how easy it is for viruses to spread across the world.

The eradication of smallpox following a WHO-led campaign saw the end to approximately 3,000 years of epidemics across the globe which caused incalculable amounts of morbidity and mortality. This was endorsed by the World Health Assembly in 1980 after the last naturally occurring case was diagnosed in Somalia in October 1977 (Brilliant and Hodakevic, 1978). In partnership with other organisations, WHO is leading the programme to eradicate polio, with only pockets remaining in parts of Africa and Asia and the campaign is close to achieving successful eradication of the wild virus (WHO, 2015).

Arguably one of the biggest pandemics of recent years is the HIV/AIDS pandemic that came to public attention in the 1980s following diagnoses of cases in the US and has since caused innumerable cases across the world and millions of fatalities. The HIV/AIDS Case Study provides further information on the origin of the virus, mortality and trends.

More recently, the Ebola epidemic in West Africa that continues into 2015 has raised concern that a pandemic of this highly fatal blood borne pathogen could occur. The unprecedented size of this epidemic is illustrated by the Ebola Case Study where from the start of the outbreak to end May 2015, over 27,000 cases including over 11,000 fatalities, largely in Sierra Leone, Guinea and Liberia have been reported. The response to Ebola had seen close collaboration of international governments, non-governmental organisations (such as WHO, Red Cross and Save the Children), military forces, and public sector healthcare providers. Many of the interventions have built on tried and tested processes developed through responding to other infectious diseases. There is also an enormous potential in smart algorithms leading to projections of disease spread and velocity. This is further discussed in section 9 that focuses on big data and technology.

Prospects and conclusions

While the mechanisms by which pathogens spread are different – e.g. blood borne vs respiratory – many of the strategic policies and principles, operational decisions, and tactical interventions are common. All have the ultimate overarching aims of reducing harm to populations and minimising disruption to society. Lessons will continue to be identified from infectious disease outbreaks, epidemics and pandemics, and policymakers will use these to inform the preparedness and response to future events. It is essential that a response is prompt enough to ensure maximum impact, but equally that due consideration is given to ensure any previous mistakes are not repeated.

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Biography

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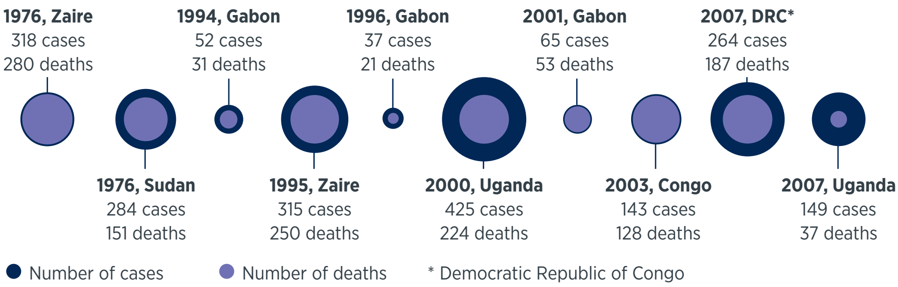
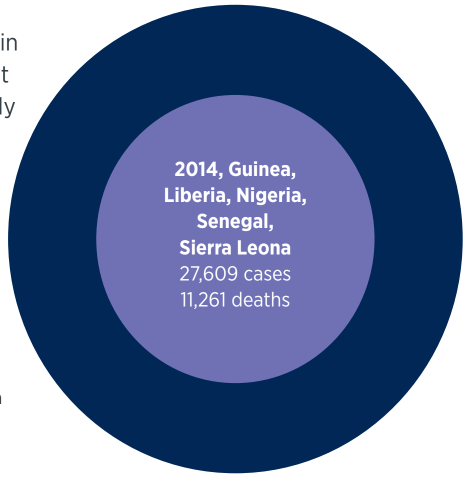
8. Case study: Ebola

Ebola virus disease (EVD) comes from the filo virus family, which occurs in humans and other primates.

Unprecedented size

Ebola virus disease (EVD), formerly known as haemorrhagic fever, was first discovered in 1972 in what is now the Democratic Republic of the Congo near Ebola River. The current outbreak dwarfs the largest historical outbreaks in Africa, which were rural and relatively easy to control. Ebola has now spread to dense urban areas, where control is harder to achieve. Since 1994 Ebola outbreaks have been occurring with increasing frequency .

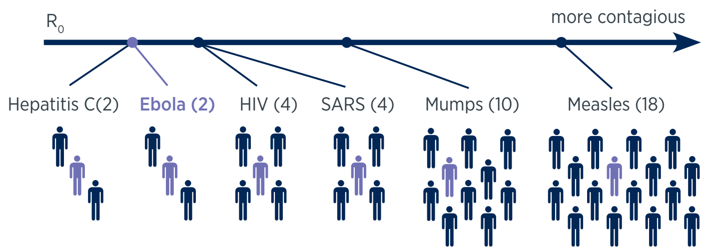




CDCP (2014)

Transmitting disease

Ebola is spread by contact with an infected person's bodily fluids, but is less contagious than many common diseases, such as mumps and measles. In the current outbreak, **each person with Ebola will infect 1 - 2 other people**. However, the death rate from Ebola is very high, there are **very limited treatments** available and effective vaccines are still only just being developed.



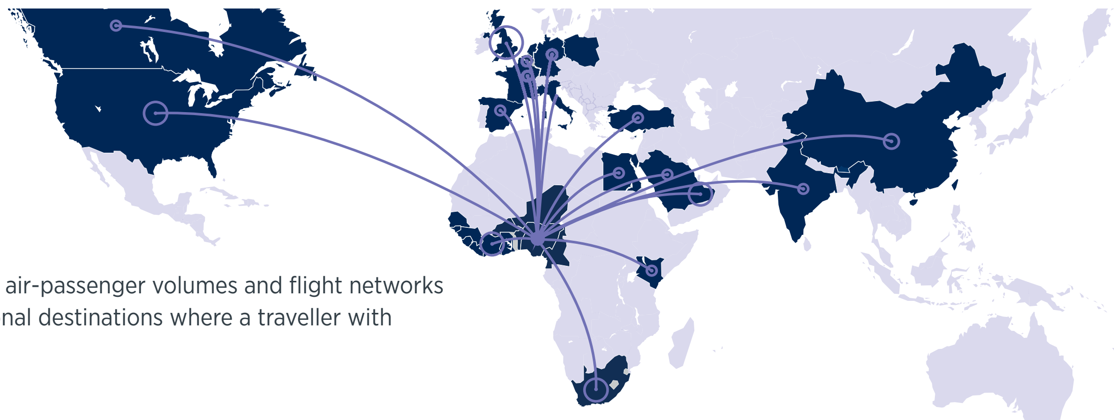
Althaus (2014)

Global reach

Number of passengers per week

6000+
3000 - 6000
1500 - 3000

Modelling of historical air-passenger volumes and flight networks can point to international destinations where a traveller with Ebola might end up.



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9. A medical technologist perspective on pandemics

Professor Christoph Thuemmler

Detailed information on prevalence, incidence, and velocity of the vector are crucial to containment and prevention of viral and bacterial epidemics. Typically information is based on crisp medical data with high reliability in order to achieve a high level of specificity. Providing diagnostic information in “real time” in this context may mean a considerable delay due to the fact that more or less complex diagnostic procedures have to be completed in order to confirm a diagnosis and correctly identify those patients who suffer a certain condition. Local medical infrastructures are heterogeneous and of different standards so there is substantial variation in the provision of reliable “real time” information. A traditional approach employed by the US Centers for Disease Control and Prevention (CDC) includes collecting influenza-like illness (ILI) activity data from “sentinel” medical practices. Typically there is a 1-2 week delay between the time a patient is diagnosed and the moment that data point becomes available in aggregate ILI reports (Achrekar et al., 2011).

Alternative measures of monitoring pandemics

The wide distribution of social media and the free availability of timely information has given rise to discussions on alternative measures of the monitoring, management and prevention of rapidly spreading infectious diseases such as influenza. A recent report issued by Cisco has highlighted the fact that the number of smart phone subscriptions has now overtaken the world population and that mobile data will increase tenfold until 2019 (Cisco, 2015). There can be no doubt that personalisation and virtualisation of healthcare will continue and that smart phones and other mobile devices will play an increasing role in all areas of health. It is reasonable to assume that hyper-connectivity based on superfast access to the Internet will improve the outcomes for patients as recently highlighted in a report by the UK National Information Board, also in the area of infection prevention with regards to influenza and other contagious and fast spreading conditions (United Kingdom. Department of Health; National Information Board, 2015).

In several studies it could be demonstrated that it was possible to track flu pandemics by monitoring the social web using data completely independent from that commonly used for flu detection. The flu-score detector suggested by Lampos and Cristianini in 2010 showed a significant correlation (greater than 95%) with data from the UK Health Protection Agency, while Achrekar et al. were able to detect flu trends by using Twitter data. In fact the use of smart algorithms to extract information from the social web has been used successfully during the 2014 Ebola outbreak. According to an article in Scientific American health care officials relied heavily on the data glut created by countless news articles, social media feeds, medical reports and emailed on-scene accounts (Greenemeier, 2014). This is achieved through a new breed of health web pages such as HealthMap. HealthMap contains services, which are able to screen and analyze tens of thousands of web pages hourly in 15 languages leading to projections of disease spread and velocity (HealthMap, 2015). HealthMap already played a role during the 2009 H1N1 flu pandemic but since then evolved massively making use of cutting edge web service technology advances.

There are clear indications that “Bring your own device” (BYOD) strategies combined with the power of the Internet might be superior to standard procedures in the speedy detection and the monitoring of flu pandemics. However, it is unclear what level of sensitivity (the ability of a test to correctly identify those patients without the disease) and specificity (the ability of a test to correctly identify those patients with the disease) with regards to the analysis of big data originating from the social web might be achievable (Lalkhen and McCluskey, 2008). In fact Internet of Things[3] (IoT) Analytics in health and social care is an area of major future interest due to the rapid pick up of m-health technology[4] and the growth of the mobile network. Deep IoT analysis will in the future extend the available input beyond the scope of the social web and will be able to access directly data pushed by devices such as location trackers, smart pharmaceuticals and smart phones. This could complement the information obtained from the social web and also may provide information on the impact of the use of (smart) pharmaceuticals or certain behaviour pattern long before this was manually extracted from patient records.

Next generation technology

According to the European Commission global m-health turnover will grow to 18 billion Euros by 2017 with more than 100,000

[3] Internet of Things – Physical objects are seamlessly integrated into the information network, and where they can become active participants in business processes.

[4] m-Health is the delivery of healthcare services via mobile communication devices

m-health applications already on the market (EC, 2014).
On the other hand there is a global trend at the moment towards superfast broadband. The roll-out of 4G-LTE technology is in full swing, while there is a strong push towards 5G networks which will considerably improve the rapid exchange of information, reduce latency and increase the number of devices which are able to connect at any given time. A major approach towards a hyper-connected society is currently under way in the City of Munich, which explicitly includes a major teaching hospital in the city centre (Huawei, 2015).

One of the objectives is to establish more intelligent networks in order to enable context aware collaboration of machines and humans in order to improve quality of care for patients and quality of experience (QoE) for medical practitioners (Nunna et al., 2015). There can be no doubt that cross-matching of the results of big data analysis of the social web data and genomics obtained from genetic analysis of bacterial strains or viruses might be of tremendous value in the future to rapidly respond to outbreaks of infectious diseases. Clearly spatio-temporal big data analysis would be a powerful tool to support this multi-dimensional analysis of millions of datasets in next to real time.

However, it is necessary to consider ethical and legal aspects in order to create an appropriate framework to administer and police this powerful technology in a way that systematically builds confidence and trust. Although the right to be forgotten needs to be carefully weighed against the public-health requirements of modern societies the back-tracking of cross matched data to individuals must be tightly regulated (EC, 2015).

New and upcoming big data analysis strategies will improve data mining capabilities in the social web and will enable a detailed assessment of incidence and prevalence of infectious diseases. Advanced cloud strategies and 5G networks will interlink more devices than ever and increase the granularity and reliability of new screening tools.

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Biography

Dr Christoph Thuemmler is a Professor at Edinburgh Napier University and Technical University Munich and is one of the pioneers of E-health in Europe. As an internationally recognised expert he has been involved in expert committees for the European Commission such as EU/China round table on the Internet of Things and other groups. He has worked in Germany, the US and the UK before focusing more and more on smart devices and service oriented architectures in health care. His research interests lie in the area of the Future Internet including the Internet of Things, work on social technological alignment in health care and the governance of e-Health in a wider context.

10. Recent developments

Who, when and why? Mortality datasets provide a wealth of information for actuaries

The use of mortality data lies at the core of much of the research carried out by the actuarial profession. In the area of health, longevity and mortality many readers will be aware of commonly used datasets such as those from the Office of National Statistics (ONS) or WHO. There is, however, a wealth of mortality data available, much of it free to access and available online. The Institute and Faculty of Actuaries has compiled a directory of datasets which cover the UK and Ireland as well as those that give an overview of European and world data. The directory not only lists the datasets and provides links to each but also provides some detail on data points of interest to actuaries and the timeframe over which the data was collected.

It is hoped that greater access to and awareness of these datasets will enable more accurate modelling, allowing actuaries to make informed decisions regarding longevity and mortality in relation to life assurance, pensions and long term care products.

To access this free resource please visit: http://bit.ly/1JD9sPx

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Hear from subject experts and engage with fellow professionals on topical issues facing today's insurance industry. Offering 70 workshops on topics such as UK and European economic updates, capital management under Solvency II, IFRS4 Phase II, tomorrow's consumer needs and Masterclass sessions – to name a few – the programme has been designed to stimulate debate and encourage thought provoking discussions.

Whether UK based or international, the conference is open to anyone with an interest in the life sector. It offers an ideal forum to meet and exchange ideas with a broad range of professionals. If you want to get up to date on the latest thinking and innovation, this is the event for you.

Find out more details and register on: http://bit.ly/1e1g2EP

Save the date: 21 September 2015. BAJ 20th Anniversary Sessional Meeting

To celebrate the 20th year of the BAJ and generate discussion around the future of IFoA research the President, Fiona Morrison, will chair a special sessional meeting on 21 September 2015 at Staple Inn Hall, London. Plans for the event include a panel and audience discussion on the role of the IFoA journals (Annals of Actuarial Science and British Actuarial Journal), dissemination of research and how we promote the value of actuarial science research. If you are interested in the future of IFoA research and how it can achieve impact through dissemination and would like to share your views, or simply hear what others have to say, please follow the sessional programme on the IFoA website.

To follow the sessional programme, please visit:
http://bit.ly/1InKhnu

Networking Event: Telematics in Health and Care Insurance - Slave to the Machine(s), 17 September 2015, London

The insurance industry is trying to adopt new technologies and advanced services but many insurers do not know where to start or what to focus on first. We will be exploring aspects of life and health telematics, what these could look like in the insurance market of tomorrow and most importantly, what this means for the actuaries of tomorrow.

This event will take place from 17.30-19.00 on 17 September 2015 and bookings can be made at: http://bit.ly/1BHZcpo

Research in Longevity Basis Risk

The Institute and Faculty of Actuaries (IFoA) and Life and Longevity Markets Associations (LLMA) jointly commissioned a research project to develop a readily-applicable methodology for quantifying the basis risk arising from the use of population-based mortality indices to manage longevity risk.

With members from the IFoA and LLMA the Longevity Basis Risk Working Group (LBRWG) is responsible for providing oversight, direction, review and quality assurance to the third party research team who have been appointed to do the research.

The research comprised a review of existing two-population mortality models and the development of a methodology for determining the relationship between the population and portfolio mortality rates in the future.

To download the research paper and user guide please visit: http://bit.ly/1Ksl3mP **and** http://bit.ly/1GGijM9

Continuous Mortality Investigation (CMI) update

The CMI, supported by the Institute and Faculty of Actuaries, has a long history of providing authoritative and independent mortality and sickness rate tables for UK life insurers and pension funds. The CMI tables have underpinned the prudential and financial reporting of almost all these institutions.

For news on mortality projections, annuitant mortality, assurance and others, please visit: http://bit.ly/1O3p9B8

Reflecting on International Mortality and Longevity Symposium 2014: Explaining the past, exploring the future

This conference provided a multi-disciplinary forum for the exchange of information on the latest relevant research, as well as an opportunity to learn about established knowledge from a range of different disciplines, all with the aim of better understanding and managing this complex yet critical subject.

The themes for this event were:

1. Medical advances are the impact of Genetic profiling on medicine and longevity
2. The international perspective: what can we learn from elsewhere?
3. New sources of information: “big data”, risk factors
4. Practical mortality and morbidity: pricing/reserving for the long-term, underwriting, critical illness, long-term care and underwritten annuities.

11. Further reading

Pandemics

International Actuarial Association - Health Committee (2015).
Analysis on the Risk of Ebola.
Available at: www.actuaries.org/CTTEES_HEALTH/Documents/Risk_of_Ebola_Paper.pdf

Breban, R., Riou, J. and Fontanet, A. (2013).
Interhuman transmissibility of Middle East respiratory syndrome coronavirus: estimation of pandemic risk.
The Lancet 382(9893): 694-699.
Available at: http://dx.doi.org/10.1016/S0140-6736(13)61492-0

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Actuarial applications of epidemiological models.
North American Actuarial Journal, 15(1): 112-136.
Available at: http://dx.doi.org/10.1080/10920277.2011.10597612

Hayward A.C., Fragaszy E.B., Bermingham A. et al. (2014).
Comparative community burden and severity of seasonal and pandemic influenza: results of the Flu Watch cohort study.
The Lancet Respiratory Medicine, 2(6): 445-454.
Available at: http://dx.doi.org/10.1016/S2213-2600(14)70034-7

Huynh, A., Bruhn, A. and Browne, B. (2013).
A review of catastrophic risks for life insurers.
Risk Management and Insurance Review, 16(2): 233-266
Available at: http://dx.doi.org/10.1111/rmir.12011

The Lancet Ebola Resource Centre.
Available at: www.thelancet.com/campaigns/ebola

Morens, D.M., Folkers, G.K. and Fauci, A.S. (2009).
What is a pandemic?
Journal of Infectious Diseases, 200(7): 1018-1021.
Available at: http://dx.doi.org/10.1086/644537

Sharp, P.M. and Hahn, B.H. (2011).
Origins of HIV and the AIDS pandemic.
Cold Spring Harbor Perspectives in Medicine, 1(1) [Online] (22 p.
Available at: http://dx.doi.org/10.1101/cshperspect.a006841

Taubenberger J.K. and Morens D.M. (2006).
1918 influenza: the mother of all pandemics.
Emerging Infectious Diseases, 12(1): 15-22.
Available at: http://dx.doi.org/10.3201/eid1209.050979

Worobey, M., Han, G.-Z. and Rambaut, A. (2014).
Genesis and pathogenesis of the 1918 pandemic H1N1 influenza A virus. PNAS, 111(22): 8107-8112.
Available at: http://dx.doi.org/10.1073/pnas.1324197111

Antimicrobial resistance

United Kingdom. Department of Health (2013).
UK Five Year Antimicrobial Resistance Strategy 2013 to 2018.
Available at: www.gov.uk/government/publications/uk-5-year-antimicrobial-resistance-strategy-2013-to-2018

Hawker J.I., Smith S., Smith G.E. et al. (2014).
Trends in antibiotic prescribing in primary care for clinical syndromes subject to national recommendations to reduce antibiotic resistance, UK 1995–2011: analysis of a large database of primary care consultations.
Journal of Antimicrobial Chemotherapy 69(12): 3423-3430

The Economist: the spread of superbugs.
Available at: http://econ.st/1Bl5rjd

Laxminarayan R., Duse A., Wattal C. et al. (2013).
Antibiotic resistance – the need for global solutions.
The Lancet Infectious Diseases 13(12): 1057-1098.
Available at: http://dx.doi.org/10.1016/S1473-3099(13)70318-9

Lesho E.P., Waterman P.E., Chukwuma U. et al. (2014).
The Antimicrobial Resistance Monitoring and Research (ARMoR) program: the US Department of Defense response to escalating antimicrobial resistance.
Clinical Infectious Diseases, 59(3): 390-397.
Available at: http://dx.doi.org/10.1093/cid/ciu319

Smith, R.D. and Coast, J. (2012).
The economic burden of antimicrobial resistance: Why it is more serious than current studies suggest.
Technical Report. London School of Hygiene & Tropical Medicine. 38 p.
Available at: http://researchonline.lshtm.ac.uk/639028/

World Health Organization (2014).
Antimicrobial resistance: global report on surveillance.
Available at: www.who.int/drugresistance/documents/surveillancereport/en/

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