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Emerging respiratory tract infections 2

Emerging infectious diseases and pandemic potential: status quo and reducing risk of global spread

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Emerging infectious diseases are an important public health threat and infections with pandemic potential are a major global risk. Although much has been learned from previous events the evidence for mitigating actions is not definitive and pandemic preparedness remains a political and scientific challenge. A need exists to develop trust and effective meaningful collaboration between countries to help with rapid detection of potential pandemic infections and initiate public health actions. This collaboration should be within the framework of the International Health Regulations. Collaboration between countries should be encouraged in a way that acknowledges the benefits that derive from sharing biological material and establishing equitable collaborative research partnerships. The focus of pandemic preparedness should include upstream prevention through better collaboration between human and animal health sciences to enhance capacity to identify potential pathogens before they become serious human threats, and to prevent their emergence where possible. The one-health approach provides a means to develop this and could potentially enhance alignment of global health and trade priorities.

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This is the second in a Series of five papers about emerging respiratory tract infections

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Introduction

Emerging infectious diseases (EIDs) are broadly defined as infections that have newly appeared in a population or have existed but are rapidly increasing in incidence or geographical range.[1] EIDs encompass: recognised infections spreading to new areas and populations; discovery that a known disease is caused by infection; previously unrecognised infection appearing in areas where habitat is changing; a new infection resulting from changes in microorganisms; and an old infection re-emerging because it has become resistant to treatment, or due to a breakdown in public health systems.[2]

Pandemics have had a chequered history when it comes to a concise definition on which to base action. The classic definition is "an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people". Although useful as an academic method to explain the concept of pandemics, this definition has proved problematic when applied without sufficient consideration to other factors such as population immunity and disease severity.[3–5] This century has seen several global and potentially global pandemics of emerging and new infectious diseases affecting the respiratory tract (figure 1) that have illustrated the complex interrelationships between animal and human hosts, the microorganism, and the environmental factors that affect exposure or transmission.[6–11]

EIDs, which include pandemic influenza outbreaks, have risen substantially over time and are dominated by zoonoses (60%) of which most (72%) originate in wildlife.[12] Emergence occurs at the human–animal interface, when animal infections breach species barriers to infect human beings, the population in which they are often first identified. In many instances identification occurs many years after the breach.[12]

During the past 40 years, EIDs that have been identified range from Ebola and Marburg haemorrhagic fevers to AIDS, severe acute respiratory syndrome (SARS), influenza A H5N1, paramyxovirus infections (Hendra and Nipah viruses), variant Creutzfeldt-Jakob

Key messages

- Emerging infectious diseases (EIDs) with pandemic potential are a major worldwide threat to global health security.
- Most new infectious diseases outbreaks with pandemic potential have been of zoonotic origin.
- A spectrum of EIDs has occurred in the past 40 years, ranging from Ebola and Marburg haemorrhagic fevers, severe acute respiratory syndrome (SARS), influenza A (H5N1), verocytotoxin-producing *Escherichia coli* O157 to the recently discovered Middle East respiratory syndrome coronovirus (MERS-CoV).
- EIDs are estimated to have caused hundreds of billions of dollars' worth of damage in the last 20 years; between 1997 and 2009 this cost amounted to US$80 billion.
- The phases of pandemics have been simplified to four from the six described previously—these are now uncoupled from action at the country level with member states retaining responsibility for their own national risk management plans.
- This approach includes an Emergency Risk Management for Health Framework. (ERM-H) and the development of the Pandemic Influenza Preparedness Framework
- Driven by compelling health-related and economic arguments for earlier interventions to prevent and mitigate emerging infections, the one-health approach has garnered increased momentum in the last decade.
- Although there have been substantial improvements in international surveillance and sharing of information, several important global incidents have occurred in the last 10 years that highlight tension developing between countries and international organisations when commercial and political interests override public health priorities.
- An important need exists for establishing trusting and meaningful international collaborations between the animal, human, and environmental health sectors to help with rapid detection of potential pandemic infections and rapidly initiate public health prevention and control guidelines and interventions.

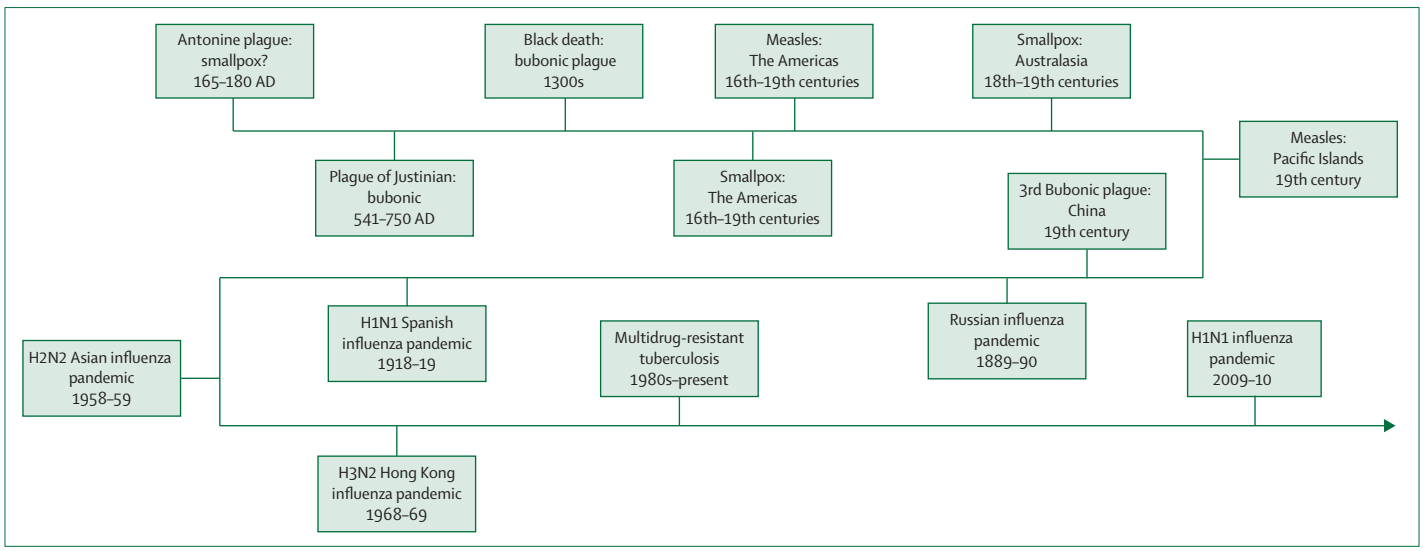

Figure 1: **A timeline of major pandemics transmissible through the respiratory tract**[6-11]

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disease (vCJD), bovine spongiform encephalopathy (BSE), and foodborne infections caused by verocytotoxin-producing *Escherichia coli* O157.[13,14] More recently, the emergence of Middle East respiratory syndrome coronavirus (MERS-CoV) has also been linked to an animal source—dromedary camels.[15] We review the infectious diseases affecting the respiratory tract with pandemic potential and discuss economic, political, and scientific measures required to minimise risk of global spread and lessons from non-respiratory EIDs that might inform planning for respiratory pandemic events.

Minimising risk of pandemic influenza

For influenza pandemic preparedness, global and national response systems need to balance the apocalyptic-like risk of a repeat of the great pandemic of 1918–19, which was estimated to have infected some 500 million people worldwide with tens of millions of deaths, and a worldwide over-reaction to a milder, less severe outbreak of the influenza virus. Influenza virus's great versatility, persistence, and potentially rapid spread and severity means that optimising global mechanisms to respond to it will always be a work in progress.[16] WHO has published interim guidance on pandemic influenza risk management that describes pandemic phases along a continuum according to a global average of cases over time, based on continued risk assessment and consistent with actions linked to a broader emergency risk management framework (figure 2).[17] The new guidance builds on recommendations stemming from a WHO review of the coordinated response to the 2009 H1N1 pandemic,[4,16,17] and substantial changes have been made to the pandemic preparedness plan (the panel shows a summary of the guidance).[17] There is a new approach to the global phases of pandemics: simplified to four phases, these are now uncoupled from action at the country level with an emphasis on providing guidance and Member States retaining responsibility and flexibility for their own national risk management plans. The plan now recommends adopting an all-hazards approach using the Emergency Risk Management for Health Framework (ERM-H) and embedding aspects of planning at every level of society including key aspects of determining pandemic influenza risk (ie, transmissibility, severity of disease, and likely effect in national action plans). The development of the Pandemic Influenza Preparedness (PIP) Framework for the sharing of influenza viruses and access to vaccines and other benefits brings together WHO Member States, WHO, industry, and other stakeholders to improve and strengthen the sharing of influenza viruses with human pandemic potential, and achieve more predictable, efficient, and equitable access for countries needing vaccines and medicines during future pandemics; the framework therefore recognises that there is an ethical dimension to pandemic planning.[18]

Interventions to interrupt transmission

Attention has focused on attempts to assess the effectiveness of interventions that might be expected to mitigate the effect of pandemics, especially to the 2009 H1N1 pandemic, but the results of these have not been helpful because, for epidemiological reasons, they have not been able to produce consistent evidence of effect or of lack of effect.[19,20]

Thus, whereas there is a high degree of confidence in handwashing as an intervention, there is much less certainty about the contribution of mask wearing and social distancing, including the contribution of school

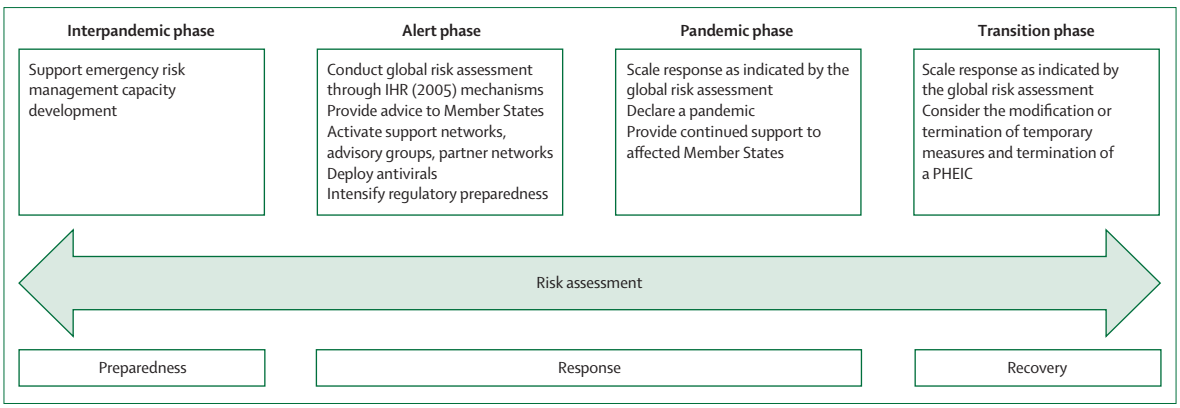

***Figure 2*: WHO continuum of pandemic phases with actions for risk management**
IHR=International Health Regulations. PHEIC=public health emergency of international concern.

closures in the 2009 pandemic, and the use of thermal screening at ports has been challenged.[21–26] Importantly, there is controversy about the role of medical interventions such as prophylactic use of antiviral drugs, and of preventive measures that could be taken at the animal–human interface.

The end result of this uncertainty is that science cannot provide the definitive advice and cost-effectiveness information that politicians seek in making decisions about investment in pandemic preparedness. The fine balance between being perceived to over-react or being perceived to under-react looks different from the political and the scientific perspective.[26,27]

Economic costs of tackling EIDs

Pandemic influenza planning (and planning for EIDs) is based on a combination of scientific, economic, and political drivers. In economic terms, EIDs are estimated to have caused hundreds of billions of dollars' worth of damage in the last 20 years.[28] A 2012 World Bank study detailing economic factors about emerging infection control estimated that economic losses from the six major outbreaks of EIDs between 1997 and 2009 for which good cost information was available amounted to at least US$80 billion. These included Nipah virus, West Nile fever, SARS, highly pathogenic avian influenza, BSE, and Rift Valley fever (figure 3).[29]

Costs in controlling future influenza pandemics and other large EID outbreaks will probably continue to rise. The UK spent an estimated $1·8 billion on the 2009 H1N1 influenza pandemic including an estimated $675 million on stockpiling oseltamivir and zanamivir as prophylaxis and treatment (the USA spent an estimated $1·3 billion on stockpiling for the same reason).[24,30] The recent systematic review published by the Cochrane Collaboration that showed the effectiveness of both drugs in preventing and treating influenza in healthy adults and children has not been proven raises serious concerns on the cost-effectiveness of national stockpiling strategies as part of a pandemic preparedness plan.[30] However, this evidence will need to be interpreted pragmatically from a political perspective if there are no alternative mitigation strategies available. Rationalising prevention and control strategies across disease areas and an all-hazards approach to pandemic preparedness could become increasingly necessary as the strain of burgeoning costs affect all areas of health care and delivery.[17]

In recent years, the principles of equity, justice, and beneficence have also emerged as key issues for pandemic planning, to ensure that countries benefit from the sharing of clinical samples[18] and the ethics of research in emerging diseases.[31]

Three seminal events are important in understanding how well we are prepared for the next newly emerging infection with pandemic potential: March 2003—the start of the outbreak that had the potential to become pandemic—SARS; April 2009—the start of the outbreak that became a pandemic—H1N1; September 2012—the start of the pandemic that might never be—MERS-CoV. Each of these events built on lessons identified from previous experiences, each showed how we can incrementally improve global public health responses, but each also showed failures to learn and improve.

Pandemic, SARS, and lessons identified

Much of the lessons identified following the 2009 pandemic (and SARS and MERS-CoV) focused on improving the detection of, and response to, the early stages of a newly emerging (or re-emerging) infection.[4,16,32]

Recommendations to national and international organisations related to surveillance, data collection and sharing, how to define better the severity of an emerging infection and correlate the public health response better with the effect on public health, how to improve diagnostic capacity, and how to develop and deploy medical countermeasures quicker.[4]

As a consequence, international and national planning has improved. Internationally, the value of global surveillance systems and epidemic intelligence systems

Panel: **Evolving approach to pandemic influenza preparedness: the interim WHO guidance**[17,18]

Coordination under the International Health Regulations (IHR, 2005)

The International Health Regulations (2005) are binding upon 196 States Parties and provide a global legal framework to prevent, control, or respond to public health risks that might spread between countries including serious events that endanger global public health, specified by the regulations as public health emergencies of international concern (PHEICs). A PHEIC is defined as "an extraordinary event which is determined to constitute a public health risk to other States through the international spread of disease and to potentially require a coordinated international response". This definition implies a situation that: is serious, sudden, unusual, or unexpected; carries implications for public health beyond the affected state's national border; and might require immediate international action. The responsibility of determining whether an event is within this category lies with the WHO Director-General and requires the subsequent convening of a committee of health experts—the IHR Emergency Committee.

Pandemic phases

The pandemic influenza phases show WHO's risk assessment of the global situation regarding influenza viruses with pandemic potential that are infecting human beings. These assessments are based on evolving virological, epidemiological, and clinical data. The global phases—interpandemic, alert, pandemic, and transition—describe the spread of the influenza virus subtype, taking account of the disease it causes worldwide. As countries face different risks at different times they are advised to develop their own national risk assessments and management plans while taking into consideration the information and support provided by WHO.

Pandemic Influenza Preparedness (PIP) Framework

The framework provides a mechanism for sharing of influenza viruses and access to vaccines and other benefits and brings together Member States, industry, other key stakeholders, and WHO for this reason. The framework, effective as of May 24, 2011, comprises three core components. Virus sharing, whereby Member States share PIP biological materials to ensure ongoing global monitoring and risk assessment, and the development of safe and effective influenza vaccines. Benefit sharing, whereby Member States and WHO aim to ensure that benefits from the sharing of PIP biological materials are made more accessible and available to countries based on public health risk and need. And lastly, governance and review. The framework puts in place an oversight mechanism with three pillars. The World Health Assembly oversees implementation of the PIP Framework, the WHO Director-General promotes its implementation, and the Advisory Group provides guidance to the Director-General, monitors PIP Framework implementation, and reports annually to the Director-General on progress. More broadly, WHO acts as the secretariat for implementing the PIP Framework and works with private and public partners to help in achieving results as efficiently as possible.

Risk assessment and the Emergency Risk Management for Health Framework

The national risk assessment process for pandemic preparedness should analyse three essential indicators: transmissibility, severity of disease, and impact. The Emergency Risk Management for Health Framework describes measures to manage risks through prevention and mitigation, and preparing for, responding to, and recovering from emergencies including influenza pandemics. This all-hazards approach is recommended for national influenza risk management plans and includes action across six key domains: policies and resource management; planning and coordination; information and knowledge management; health infrastructure and logistics; health and related service; and community capacities.

such as ProMed and Global Public Health Intelligence Network (GPHIN) have been recognised and new initiatives such as the Early Alert and Response System (EARS) established by Global Health Security Initiative Member States[33] and Connecting Organizations for Regional Disease Surveillance (CORDS)[34] are emerging. The potential of these systems, and the value of public data to map possible outbreaks have been confirmed.[35] Many national plans have been revised and have incorporated learning from the 2009 pandemic: the revision and global acceptance of the International Health Regulations (IHR) after SARS has improved international vigilance, collaboration, and cooperation; the globalisation of social media has driven greater transparency—or greater awareness and exposure when there is a lack of transparency; and plans have a greater focus on risk assessment and risk communication.[16,17,24] The SARS outbreak also showed the willingness of the global community to collaborate in real time in all aspects of outbreak containment including outbreak investigation, clinical management, and laboratory virology and discovery.

Substantial improvements have been made in international surveillance and sharing of information, in trust between countries and between public health authorities, and there is a more positive approach to sample sharing and genomic sequence sharing. The response by the Chinese authorities to H7N9 infections in China has shown how much the national and international response has improved.[36] Collaborative research has not had the same success, as shown in the present MERS-CoV outbreak.

Potential improvements in stockpiling and vaccine development and manufacturing capability were driven

by the continued circulation and periodic re-emergence of the influenza A H5N1 virus and the resulting pandemic planning, but given even greater urgency and political drive in light of the 2009 influenza A H1N1 pandemic experience.

Important work has been done to engage the pharmaceutical industry in the ethics of virus isolation, vaccine development, and the practicalities, but substantial challenges remain and there is still inequity across the world.[16]

The development of the H7N9 and MERS-CoV stories shows that there have been improvements in worldwide response and in information sharing, but global preparedness is still not where it needs to be. Although much has been published about MERS-CoV,[37–42] epidemiological case-controlled and clinicopathological studies are needed to understand the origins and transmission dynamics of MERS-CoV to human beings.[22] Outbreaks of MERS-CoV in hospitals in Saudi Arabia also call for strengthening and implementing basic infection control measures to prevent infection of health-care workers.[43]

Although there have been substantial improvements in worldwide preparedness for emerging infections and potential pandemics, there are still two issues to be tackled: building trust and moving preparedness efforts upstream to look at preventing emerging zoonoses.[44]

Establishing trusting global collaborations

There is an urgent need to build trust between countries and between public health authorities to ensure maximum cooperation and transparency. In the past 10 years there have been important global incidents that emphasise the tension between countries and international organisations when commercial and political interests are perceived to have an undue effect on global pandemic preparedness policy.[4,16] This effect is further exacerbated when inequity in access to technology, expertise, and the best diagnostic, prophylactic, and treatment methods are prevalent. An example is Indonesia's refusal in 2006–07 to share samples of influenza H5N1 isolates with WHO in direct protest to the inequitable sharing of virus samples and vaccine development technology.[43] Lack of trust in WHO's response was evident following the H1N1 pandemic in 2009 too, including from the Council of Europe which highlighted potential conflicts of interest of individual members of the emergency committee convened by WHO to respond to the pandemic—linking them to industry, and noting WHO's policy on keeping the membership of the committee secret. Substantial shortfalls and delay in distribution of vaccine supplies to low-income and middle-income countries were also emphasised by subsequent reviews of the 2009 H1N1 pandemic response.[4,16,45]

The Indonesian Government's call for more equity and developments since the H1N1 2009 pandemic have led to several positive initiatives.[46] Within WHO's PIP Framework, discussions have evolved to improve virus sharing in the context of recognising the need for shared benefits. Indonesia is now one of several low-to-middle income countries that are developing or have already developed in-country vaccine manufacturing capacity—others in the WHO-supported programme of technology transfer include Brazil, China, Egypt, India, Kazakhstan, Mexico, South Korea, Romania, Serbia, South Africa, Thailand, and Vietnam. Initiatives such as the creation of a technology transfer programme at the Netherlands Vaccine Institute (RIVM) to provide training in the embryonated egg production of inactivated influenza vaccine are helping to achieve this aim.[47,48]

There are still barriers to effective international cooperation and benefit sharing despite the number of reports emphasising the importance of this key facet of pandemic preparedness. Substantial agreement exists across the public health community about how global collaboration should work, there is greater political acceptance of the value of such collaboration, but there are still barriers arising from commercial and academic drivers. China, with its direct experience of SARS and the economic and political consequences of not being ready to respond, has shown a good example by facing the economic challenges of H7N9.[31] The experience of Saudi Arabia with MERS-CoV highlights other barriers, such as ineffective international collaboration and partnerships.[44]

Despite a declared willingness to collaborate and share, and the publication of substantial epidemiological and microbiological information about early coronavirus cases and outbreaks, there appeared to be delays at times

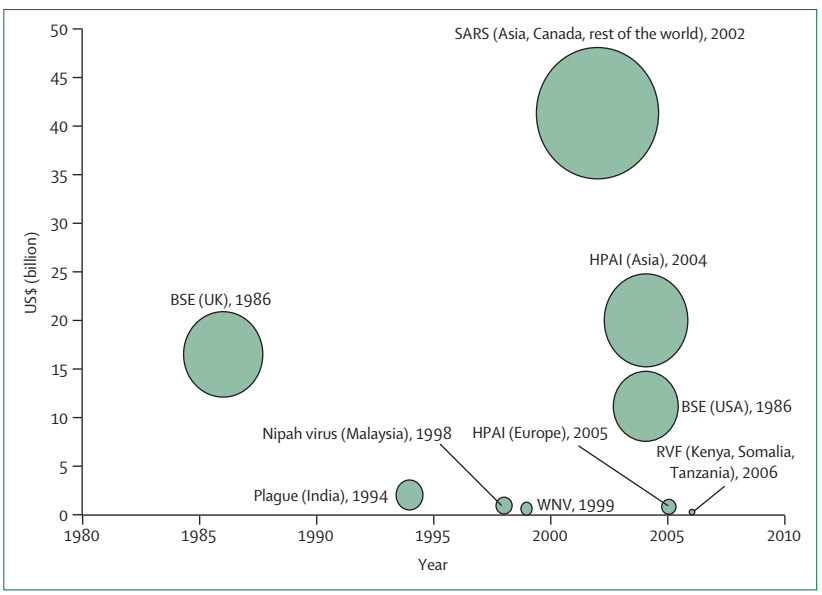

Figure 3: **Estimated cost of selected emerging zoonotic diseases (1986–2006)**
SARS=severe acute respiratory syndrome. BSE=bovine spongiform encephalopathy. HPAI=highly pathogenic avian influenza. RVF=Rift Valley fever. WNV=West Nile virus. Adapted with permission from The World Bank.[29]

in sharing information between public health authorities before it was accepted for peer-reviewed publication, and in sharing clinical and viral samples for public health use without prejudice to subsequent commercial development of products derived from that material.

Conflicts of interest that are barriers to trust will probably continue as long as academic and research organisations are judged primarily by their publication record or there is an associated commercial imperative. An urgent need exists for sufficient global public health capacity that is free from these constraints to allow free and rapid sharing of information and samples. Politicians are beginning to understand the importance of tackling these issues. The Global Health Security Action Group (GHSAG) has initiated work to develop sample sharing protocols and arrangements that build on the WHO PIP Framework but that move on from influenza viruses to include any organism that might lead to a public health emergency of international concern (PHEIC under the IHRs). The GHSAG initiative is initially intended to focus on sample sharing between the countries in the GHSAG but it will be open to other countries to use the GHSAG-agreed protocols for sharing, and these protocols should encourage and help with sharing without compromising the commercial rights of the sending countries and without prejudicing future benefit sharing.[49]

Specific capacity building activity could help to increase trust and engender a true spirit of global cooperation. The positive global experience gained from the development of the Supranational Reference Laboratory (SRL) Network for the surveillance of multidrug-resistant tuberculosis under the Stop TB partnership could serve as a template for the development of a more integrated global laboratory surveillance, diagnostic, and vaccine development and manufacture network working across a series of high priority EID pathogens.[50]

The eventual aim of such an initiative would be to ensure that sufficient numbers of biosafety level-3 (BSL-3) and BSL-3 (adapted for animals) reference laboratories exist in every WHO region to serve the needs of its member countries and peoples.[51] Benefits of a global network would include a greater capacity of regions to respond to local and international EID threats more quickly and efficiently, and, importantly, to retain human resources and expertise within those regions. The latter could have an additional benefit in aiding efforts to curtail the brain drain of scientists and technical experts from low-to-middle income countries to more developed regions of the world.

The USA has launched a high-level initiative (the Global Health Security Agenda) to bring together countries to work on these issues.[52] Although laboratory capacity should be a clear priority within this, the programme must be seen as an opportunity to serve as a catalyst for developing a community of trust within the global public health system, and can provide clear support to strengthening the IHR framework, which underpins the obligations of WHO Member States in responding to pandemics and other PHEICs.

Prevention

Action is still focused on detection and response, not prevention. Most of the activity in global pandemic preparedness will be of benefit only after the infection has emerged; this is essential to global security, as preventive efforts cannot be entirely effective. However, the biggest gains might come from preventing infections from emerging or from jumping to human beings rather than from managing them after they have done so.

Going upstream to detect and stop these new events at source will require greater cooperation and investment in bringing together human and animal epidemiology and microbiology.[53] In the context of increasing globalisation and the potential effects of climate change on ecosystems, the need for better understanding of how diseases emerge and cross to human beings is urgent.

EIDs, including pandemic respiratory tract infections such as influenza and MERS-CoV, share a common theme: infection is often first detected in human populations in which an emergency clinical response and hypothesis-generating outbreak investigation begin before the source of infection is understood. Initial recommendations for control are therefore, out of necessity, precautionary—based on evidence from past and present outbreaks that have similar epidemiological patterns, and for which the cause is known—and these precautionary measures can cause severe negative economic effects. Although modern methods such as genetic sequencing offer solutions for the identification of potential pathogens, predicting their emergence and their behaviour in human populations is still very difficult. A better understanding of the prevailing disease ecology and investigations into the dynamics of infectious agents in wildlife could act as a better means of preventing outbreaks in livestock and people at source.[54]

Global efforts to control EIDs might be better served by directing greater attention and resources to prevention of emergence at the source by learning from past emergence events and by understanding and mitigating the factors, or determinants, that affect animal infection. These determinants include human-induced changes in natural environments, urban areas, and agricultural systems; raising and processing animal-based foods; and the roles of worldwide trade, migration, and climate change. Many evidence-based policies encounter political barriers, especially when commercial benefits are at stake. With agriculture, primarily a profit-driven industry, prevention and mitigation strategies that are most easily accepted voluntarily are those that are cost effective and have no negative effect on profit. For more costly policy options, enforceable legislation might be

the only way they can be implemented. Interventions and strategies that are cost effective for the animal industry (and associated sectors such as trade, commerce, and the environment) will have a better chance of being accepted than others.[29,53,54]

One health

Driven by compelling health-related and economic arguments for earlier interventions to prevent and mitigate emerging infections, the one-health approach has garnered increased momentum in the past decade.[29]

The American Veterinary Medicine Association defines the one-health concept as the collaborative effort of many disciplines—working locally, nationally, and globally—to attain better health for people, animals, and our environment. This approach to preventing and mitigating the effects of emerging infections, and zoonoses such as influenza, aims to address potential or existing risks that begin at the animal–human–ecosystems interface. There is broad-based consensus on this approach and many national governments, international agencies, and global organisations are collaborating to implement the aims of one health.[55,56]

Global organisations formally endorsing the one-health approach include WHO, Food and Agriculture Organization (FAO) of the UN, World Organization for Animal Health (OIE), UN System Influenza Coordination (UNSIC), and the World Bank. Additionally, the European Commission and the US Centers for Disease Control and Prevention (CDC), the US Agency for International Development, the Bill & Melinda Gates Foundation, and the Wellcome Trust now support a wide range of research-related efforts in the one-health arena.[56,57] WHO, OIE, and FAO have created the Global Early Warning System (GLEWS), a platform shared by the three organisations to improve early warning and risk assessment on zoonoses and EIDs worldwide.[58]

A strategic alignment between the three organisations, the tripartite agreement, has been evolving over the past decade. It was originally conceived with a principal aim to develop a coordinated approach with shared responsibilities to contain the emergence and spread of human and animal diseases. In recent years this has expanded to include other non-disease-specific collaborations, including antimicrobial resistance arising from human and non-human use of antimicrobials. With the development of the Global Early Warning System and the possibility for further integration of harmonised surveillance, alert, and response systems across disease areas, the potential exists to further improve worldwide pandemic preparedness plans through this agreement. The FAO and OIE have already developed a joint Network of Expertise on Animal Influenza (OFFLU) to support international efforts to monitor and control infections of avian influenza.

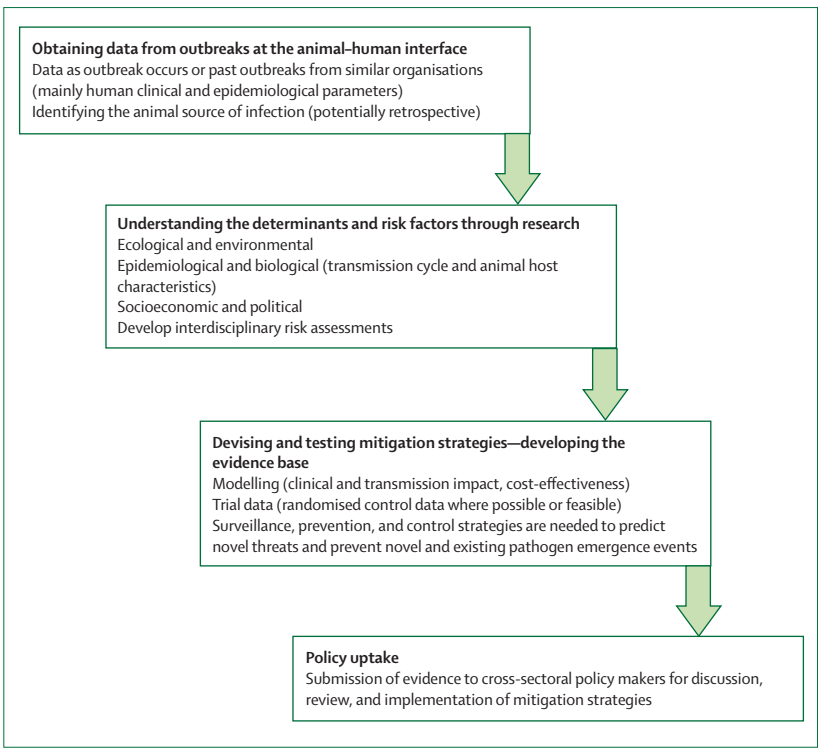

Figure 4: **Turning evidence into policy—shifting the paradigm on zoonotic emerging infectious disease control**

Links between OFFLU and the WHO Global Influenza Surveillance and Response System (GISRS) have been strengthened, facilitating a free exchange of information and the establishment of joint technical projects between the networks.[59] Strengthening one-health partnerships at the global level could eventually lead to a further evolution of the global influenza pandemic plan; one which embeds a one-health approach explicitly and incorporates a mechanism for detecting and responding to both animal and human pandemics worldwide.

Ultimately, translation of the developing one health knowledge base into policy can help shift the paradigm from detection, assessment, and response further upstream—to prevention of emerging infections at the source—thus better protecting animal and human health, and protecting economies (figure 4).[53] However, gaps in knowledge and best practice remain, and implementation of the one-health approach is variable and under-funded, particularly in developing countries. Sustaining and building on the progress that has been made is crucially important.[29]

The global trend of centralising livestock production for meat, dairy, and poultry products on larger farms, as opposed to smaller more decentralised holdings, might provide an opportunity to introduce standards and strategies for surveillance of animal populations that would have been previously more difficult to regulate and maintain. International Organization for

Search strategy and selection criteria

We searched for articles in the English language from PubMed and WHO publication websites, Embase, and the US Centers for Disease Control and Prevention website using the search terms "pandemic", "emerging", "new", and combined these with the terms "infectious diseases", "global spread", and "risk" for the period Jan 1, 1980, to Jun 30, 2014. Substantive reviews identified on the subject were also referenced.

Standardization (ISO) certification and quality assurance for large centralised livestock and poultry holdings in both developing and developed countries could be linked to the maintenance of a basic surveillance system for detecting infections in livestock, which could be achieved by one-health engagement with technical committees developing ISO standards.[60] Concerns about increased costs of production from operating such surveillance systems could be offset by the benefit of earlier detection and control of livestock outbreaks.[61] The advent of new technologies allows for real-time syndromic surveillance systems across both animal (livestock) and human populations by the use of tablet and mobile phone-based platforms for data collection.[57]

If such measures prove to be cost effective, governments, ministries of trade, commerce, agriculture, global organisations such as the World Trade Organization, and funding institutions such as the World Bank should be engaged to promote uptake. If they are not shown to be cost effective, newer technologies must be developed that are. Clearly any policy or strategy that is developed needs careful risk assessment to ensure that low-income countries do not suffer from unfair trade restrictions, and that development, food prices, or food availability are not compromised. A careful balance must be struck between positive measures (access to increased funding) and negative measures (increased regulation). The World Bank estimates that the annual funding needed for 60 low-income and 79 middle-income countries to bring their animal infection prevention and control systems up to OIE and WHO standards ranges from $1·9 billion to $3·4 billion.[29,61]

To broaden the funding base outside the traditional donor base for one-health research and improve control strategies at the animal–human interface, high-income countries that are large livestock and poultry importers and exporters should be encouraged to contribute more to these efforts. Although much of the work on global pandemic preparedness has focused on influenza viruses, there are parallels and lessons to be learned from global responses to other zoonotic viral infections that have spread in recent years outside their geographical zones as illustrated by Rift Valley fever.[62]

Following the outbreak of Rift Valley fever, an arthropod-borne zoonotic EID in Saudi Arabia in 2000—the first such occurrence outside of Africa—there was a ban on imports of live animals from Somalia until 2009. The ban was only partly effective with animals from Somalia crossing to Saudi Arabia through other intermediate countries. Upgrading of port quarantine and livestock export facilities at Bossasso and Berbera, through Saudi investment in ensuing years, however, ensured that Somalia was able to export animals to more countries and gave importing countries the reassurance that animals being purchased were disease free and operations were in compliance with international OIE standards. This bilateral agreement benefited both countries in trade, human, and animal health terms and could be a template for other one-health initiatives.[63] Wealthy Gulf Arab states are bilaterally supporting the development of other agricultural and livestock systems in low-income countries as a way to strengthen food security and an opportunity exists to incorporate control programmes for EIDs, such as influenza and corona viruses, in that process.[64] The one-health approach to EID control potentially aligns national, global, and health and trade priorities.

Conclusions

Global preparedness for emerging infections with pandemic potential has improved by learning from past experiences. However, the focus has been too far downstream rather than on more effective prevention and there are still barriers to the cooperation and collaboration that all agree is essential. At present, evolving initiatives on global health security and a one-health approach could, with sufficient goodwill, trust, and political support, substantially improve the situation and reduce the threat from future incidents. An essential element of global pandemic preparedness is to recognise the legitimate, but sometimes contradictory, interests of the scientific and the political communities, and to overcome the obstacles that impede the development of trust and true global collaboration.

Contributors

BM and DLH coordinated the writing of this Series paper and wrote the initial draft outline. All authors contributed relevant text and finalised the manuscript.

Declaration of interests

We declare no competing interests.

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