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ANALYSIS

Prevention is better than cure for emerging infectious diseases

Emerging infectious diseases have the potential to cause considerable morbidity, mortality, and economic damage. **David Heymann** and **Osman Dar** explain why we need to shift the emphasis from responding to emerging infections once they are detected to preventing them from occurring in the first place and describe one initiative that is working to achieve this

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Emerging infectious diseases (emerging infections) have caused tens of billions of dollars worth of damage in the past 20 years and the costs are continuing to rise.^{1,2} Emerging infections can be new infections, such as HIV (when first discovered), which is thought to have emerged in human populations from a non-human primate; or existing infections that are becoming more common or spreading in geographically new areas as a result of changes in the micro-organisms or changing climate and include West Nile fever, Dengue fever, and chikungunya.³

Many people assume that emerging infections are a matter for tropical disease specialists, but they are important to doctors and policy makers, vets, farmers, traders, and economies globally. Although some emerging infections are specific to tropical areas, such as Ebola and Marburg haemorrhagic fevers, infections that emerge there can spread to other parts of the world, as seen with HIV. There are also many examples of diseases originating in non-tropical settings, including severe acute respiratory syndrome (SARS), influenza A (H5N1), variant Creutzfeldt-Jakob disease/bovine spongiform encephalopathy (BSE), and foodborne *Escherichia coli* O157 infections.^{4,5} Another problem is infections that have emerged in new forms—for example, multidrug resistant Staphylococcal and Mycobacterial species.

Over the past decades there has been increasing recognition that the way we deal with infectious disease is often reactive and too late. New diseases are often identified only after they have transferred to humans and sometimes many years after the breach in the species barrier.⁶ In this article we describe how doctors and other professions are beginning to work together to stop emerging infections earlier.

How do infectious diseases emerge?

A review of emerging infectious diseases in the past 60 years suggests that just under two thirds were transmitted from animals, with just over 70% of these from wild animals and the rest from domesticated animals.¹ For example, a recent emerging infection, Middle East respiratory syndrome coronavirus (MERS-CoV), which was first reported in 2012, may be associated with dromedary camels.⁷ Globalisation and foreign travel have resulted in new convergences of people, animals, and the environment and have altered ecosystems, providing some microbes with the opportunity to breach species barriers (box). Humans have infringed on animal habitats and international trade has lengthened supply chains,⁸ but one of the most important changes is the increased human demand for meat and animal products and consequent increase in animal husbandry, which is thought to be one significant cause of the increased emergence of novel influenza virus strains in Asia.^{9,10}

Global response when disease strikes

Countries that are members of the World Health Organization are legally required to report to WHO any emerging infectious disease that is thought to have the potential for international spread,¹¹ and WHO then notifies other countries through its information management systems and, at times, through the global alert and response network (GOARN). In 2013, two of the most important outbreaks reported to WHO were those of MERS-CoV and influenza A/H7N9 (table 1).¹²

When an emerging infection is reported to WHO, epidemiologists from WHO and the reporting country assess the risk to humans, determine the source, and try to understand whether there is continued risk of transmission. If there is thought to be an ongoing threat, measures to control spread may

Potential pathways for emergence of new disease

Change in land use—Human encroachment, mineral extraction, deforestation, habitat fragmentation, urbanisation

Food and agriculture systems—Intensified or expanded farming systems, greater livestock density, trade networks and globalisation, unregulated use of drugs and vaccines, livestock mixing patterns, biodiversity

Human behaviour—Hunting and consumption practices, cultural patterns, increased travel, breakdown of governance

Environmental systems—Climate change, natural disasters, periodic climate systems

be recommended such as surveillance, contact tracing, isolation, social distancing, vaccination or prophylaxis in humans or animals, and at times culling of animals if they remain a source of infection. Culling can have a big financial effect. During the 12 months after a causal link was established between bovine spongiform encephalopathy in cattle and variant Creutzfeldt-Jakob disease in humans the United Kingdom culled cattle, costing an estimated \$5.75bn (£3.4bn; €4bn).¹³ Culling flocks of chickens infected with H5N1 in Cambodia cost each farmer \$210—nearly double their typical monthly income—for which they were inadequately compensated.¹⁴

If the infection becomes established in human populations, the disease burden is potentially more costly. The AIDS pandemic has been estimated to have reduced the gross domestic product of African countries by 2–4%.¹⁵

One Health in one world

The economic burden of controlling emerging infections estimated from six major outbreaks between 1997 and 2009 amounted to at least \$80bn, according to an extensive study by the World Bank.² Diseases included Nipah virus, West Nile fever, SARS, highly pathogenic avian influenza, bovine spongiform encephalopathy, and Rift Valley fever. The study highlighted the importance of earlier control of outbreaks to limit both costs (figure 1) and the impact of disease. These factors have been behind the growth of the One Health approach over the past several decades (www.onehealthinitiative.com), which was reinforced by the global response to the 2005 outbreak of highly infectious avian flu.

One Health is a collaborative effort of local, national, and global specialists from a wide range of disciplines to improve health for people, animals, and our environment.¹⁰ This holistic approach aims to tackle the potential or existing risks at the animal-human-ecosystems interface by learning from past events and understanding and mitigating the determinants that influence animal infection—for example, humans changing natural environments, food production, global trade, migration, and climate change.^{10 16} Better evidence and modelling of the cost effectiveness of intervention could help break political and economic barriers to prevention of infections in animals. Modern tools like genetic sequencing have helped identify potential pathogens, but predicting their emergence in humans remains difficult. A better understanding of the disease ecology and investigations into infectious agents in wildlife could potentially prevent outbreaks in livestock and people.^{8 17}

There are some 90 One Health initiatives underway across Europe and Asia,¹⁸ and the approach has been adopted by various governments, including in the United Kingdom. The UK programme has formed the Human And Animal Infections and Risk Surveillance (HAIRS) group that each month reviews reports of animal and human infections from around the world and provides risk assessments for those that could pose a national public health threat.¹⁷

WHO has joined with the World Organisation for Animal Health and the Food and Agriculture Organisation to create the global

early warning system (GLEWS). This platform aims to improve early warning and risk assessment of zoonoses and emerging infectious diseases worldwide and has been instrumental in understanding the geographical spread of novel influenza viruses such as H5N1.¹⁹ The World Organisation for Animal Health has also modernised its worldwide information system (WAHIS) for collecting notifications for 100 priority terrestrial/aquatic animal diseases, with all countries linked online to a central server.¹⁹

The Emerging Diseases in a Changing European Environment (EDEN) project and its follow-on project EDENext was set up in 2005 and draws on expertise from scientists from many disciplines in 24 countries, involving the study of landscapes, vector and parasite bionomics, public health, and animal reservoirs of infection. Each of these factors can influence the spatial and temporal distribution and dynamics of human pathogenic agents such as tick or rodent borne diseases, leishmaniasis, and malaria.²⁰

Frameworks have been developed that could help prioritise focus areas for One Health research.^{21–23} And organisations such as USAID, the Bill and Melinda Gates Foundation, and the Wellcome Trust have in recent years started funding specific initiatives for One Health research. One aim is to identify infectious organisms in livestock and wild animals, genetically sequence them, and attempt to predict which organisms have the potential to emerge in humans, particularly in areas such as Asia and Africa where disease has emerged before. Although prediction may not be possible with current tools and understanding, the inventory of organisms will allow development of better diagnostic tests for future emergent events in humans. Research is also being conducted into the effects of antibiotic use in animal production and its relation to the development of antibiotic resistance.

Future of emerging diseases

With time, the knowledge and evidence from initiatives such as One Health should shape policy and shift the emphasis from detection and outbreak response to emerging infections, to prevention of infections at source. This may well result in better protection of animal and human health, and economies.

For emerging infectious diseases to be prevented, a greater number of skilled staff will be needed, including public health, veterinary, and environmental scientists. Internationally, universities have begun to adopt this multidisciplinary approach and now offer postgraduate masters courses in One Health to scientists from various disciplines. This may facilitate future cross discipline collaboration.

The challenge of infectious disease in developing countries is greater where funding is limited.^{2 8} 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 WHO standards ranges from \$1.9bn to \$3.4bn.²

The trend of centralising livestock production for meat, dairy, and poultry products on large farms may provide an opportunity

for introducing standards and strategies for surveillance of animal populations that would previously have been more difficult to regulate and maintain.²⁴ It has been proposed that certification and quality assurance for large centralised livestock holdings in all countries be linked to the maintenance of a basic surveillance system for detecting infections in livestock. There is concern that surveillance systems could increase the costs of meat production, but these costs could be offset by earlier detection and control of livestock outbreaks, and the cost effectiveness of this approach must be assessed. New technologies such as tablets and mobile phones now allow for real time surveillance systems to be implemented with data transmitted to a central server for analysis as soon as it is collected—potentially greatly increasing early detection of illness in animal populations.

Policies must be well thought out when commercial benefits are at stake. Strategies that are cost effective or subsidised will have a better chance of being accepted by industry. For more costly policy options, legislation may be the only way they can be implemented.¹⁷

A careful balance must be struck between positive measures such as access to increased funding and generation of knowledge and measures that may be perceived as negative such as increased regulation. For example, encouraging and broadening the use of environmental impact assessments when planning new farming and livestock initiatives in wild or uncultivated areas could be built into a regulatory framework, but work may be needed to show farmers why such measures are of value. The same is true for extraction industries that penetrate tropical forests and other previously undisturbed environments for activities such as lumbering and mining. Latin American countries, for example, have recently included a requirement for environmental assessments into the law that regulates the extraction industries.²⁵

Collaborative, multisectoral approaches such as One Health are necessary to improve the control of emerging infection, and, as with other areas of health, interventions must clearly demonstrate efficacy, cost effectiveness, and sustainability. The global approach must incorporate the human, animal, and environmental health communities and also fully engage with policy makers across other sectors such as trade and commerce.

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Key messages

Most emerging infectious diseases emerge where animals meet humans

The world's increased demand for meat has been one cause of disrupted ecosystems and increased the potential for emerging infections

Since 2005 there has been a change of emphasis from control to prevention or minimisation at the source, but more must be done to show its cost effectiveness

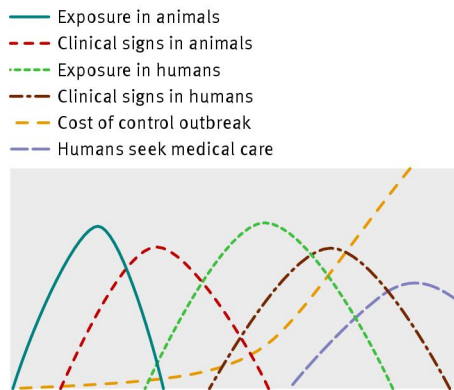
One Health brings together researchers and workers from health, agriculture, environment, and commerce to tackle the problem from all angles

It is hoped that this approach will improve human health and reduce economic costs by preventing emerging infections at their source

Table**Table 1 | Important zoonotic emerging infectious diseases reported to WHO, January to November 2013**

Emerging infection	Countries	Summary of cases	Control measures
Avian influenza A/H5N1	Cambodia, Egypt, China, Indonesia, Bangladesh, Vietnam	20 cases including 11 deaths reported in Cambodia. Sporadic reports of cases (11 in total) from other countries	Rapid response teams deployed Enhanced surveillance measures Public health education campaigns
Avian influenza A/H7N9	China	139 laboratory confirmed cases with 45 deaths (March- November 2013). Linked to live bird markets with no sustained human to human transmission	Temporary closure of live bird markets in some affected areas Culling of live birds in wholesale markets in some affected areas
Middle East respiratory syndrome corona virus	Saudi Arabia, Oman, France, Italy, Jordan, Qatar, Tunisia, United Arab Emirates, UK	150 laboratory confirmed cases and 64 deaths (September 2012-November 2013). Most case occurred in Saudi Arabia with cases in other countries in single figures. Limited human to human spread	Increase surveillance of sudden acute respiratory illness across WHO member states Elderly and chronically ill people asked to limit visit to the Hajj this year
Yellow fever	Chad, Ethiopia Cameroon, Democratic Republic of Congo	Small numbers of laboratory confirmed cases have been notified across several African countries	Increased surveillance activity and mass vaccination campaigns carried out in affected countries

Figure



Early control of zoonotic infections is cost effective and reduces human disease²