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Reshaping surveillance for infectious diseases: less chasing of pathogens and more monitoring of drivers

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Summary

Animal health surveillance, despite its name, tends to focus on looking for disease. Often this involves searching for cases of infection with known pathogens ('pathogen chasing'). Such an approach is both resource intensive and limited by the requirement for prior knowledge of disease likelihood. In this paper, the authors propose the gradual reshaping of surveillance towards the systems level, focusing on the processes ('drivers') that promote disease or health, rather than on the presence or absence of specific pathogens. Examples of relevant drivers include land-use change, increasing global interconnectedness, and finance and capital flows. Importantly, the authors suggest that surveillance should focus on detecting changes in patterns or quantities associated with such drivers. This would generate systems-level, risk-based surveillance information to identify areas where additional attention may be needed, and, over time, inform the implementation of prevention efforts. The collection, integration and analysis of data on drivers is likely to require investment in improving data infrastructures. A period of overlap would allow the two systems (traditional surveillance and driver monitoring) to be compared and calibrated. This would also lead to a better understanding of the drivers and their linkages, and thereby generate new knowledge that can improve surveillance and inform mitigation efforts. Since surveillance of drivers may give signals when changes are occurring, which could act as alerts and enable targeted mitigation, this might even enable disease to be prevented before it happens by directly intervening in the drivers themselves. Such surveillance focused on the drivers could be expected to bring additional benefits, since the same drivers promote multiple diseases. Further, focusing on drivers rather than pathogens should enable control of currently unknown diseases, making this approach particularly timely, given the increasing risk of emergence of new diseases.

Keywords

Drivers – Health – Infectious disease – Pathogen – Prevention – Surveillance – Systems-level surveillance.

Introduction

Infectious disease surveillance is a cornerstone of epidemiology and disease management. It reveals the amount and distribution of disease(s) in populations; enables detection of infected individuals or groups in order to target control efforts; helps to prevent outbreaks through early detection of pathogen incursion; and facilitates the demonstration of specific geographic regions as being free from infection to facilitate international travel or trade [1]. Knowledge gleaned from these applications helps to understand where disease occurs (e.g. in which locations and species), how and why diseases spread, and the impact of control measures. Together, these insights should lead to better disease control in the future. But this implies the aim is to remove or prevent disease, actions that are not necessarily synonymous with promoting health. This distinction is important because it will affect how surveillance is designed and conducted and, ultimately, how success is defined.

Health is a social construct, meaning its definition and importance vary with people's personal and social values, and this happens in a dynamic way, concurrent with societal change [2]. Further, health is not simply the absence of disease [3] and the meaning of 'in good health' is commonly an opinion (professional or personal) and a relative rather than an absolute condition [4]. Yet, definitions of animal health still rely largely on the absence of disease or the observation of 'normal' behaviour and functioning. It has been said that 'health cannot be measured solely by what is absent but rather by characteristics of animals and their ecosystem that affect their vulnerability and resilience' [5]. This can apply to both human and non-human animals and invites a closer look at the processes that affect the vulnerability and resilience of living systems, processes that may drive (or protect against) disease emergence.

Most current disease surveillance in humans and animals focuses on 'chasing pathogens': spending effort trying to find known hazards [1]. The problem with this approach is that it usually requires prior knowledge of each pathogen to know what to look for and where best to look. It is thus reactive. Surveillance for new pathogens is possible but is, by necessity, non-specific and relies on looking for unusual trends. Furthermore, it is not possible to demonstrate freedom from a disease – which in animal health is often essential for trade purposes, and in human health may affect the ability to travel, as seen during the coronavirus disease 2019 (COVID-19) pandemic – if the disease is not yet known to science. Since novel pathogens are constantly emerging, the next pandemic may be caused by a new virus or bacterium, or even a new form of infectious material.

Consequently, there is a shared interest across disciplines in targeting surveillance to enable early detection of pathogens in human, animal and plant populations [6]. Limited evidence is available, however, on what factors actually improve early detection [7] and on the usefulness of novel digital surveillance approaches that are increasingly being integrated into public surveillance systems [8]. A possible way to solve some of these challenges might be to conduct surveillance at a systems level, focusing on the processes ('drivers') that promote disease or health, rather than on the presence or absence of specific pathogens. Such an approach would be expected to bring additional benefits since many diseases are promoted by the same drivers. Further, focusing on drivers rather than pathogens has the potential to improve the performance of surveillance by enabling alerts, and therefore increasing the likelihood of early detection and response to currently unknown (i.e. yet-to-emerge) diseases.

Drivers of disease emergence

The last two decades have seen an increasing realisation of the importance of major processes driving disease emergence, sometimes called drivers. Drivers of disease can be defined as processes linked to humans, animals, plants and the environment that lead to the necessary conditions for a pathogen to emerge, spread and cause disease in susceptible populations [9, 10, 11]. Most, if not all, are anthropogenic [12]. Examples and some of their impacts include:

- climate change, which may affect geographical distributions of hosts, pathogens and vectors as well as reducing host resilience against infection [13];
- deforestation and habitat disturbance. The risk of outbreaks of zoonotic and vector-borne diseases – as a result of promoting contacts between previously separate viruses and people or animals – has been positively correlated with deforestation, mostly in tropical countries, and with reforestation, mostly in temperate countries [14]. This latter finding is surprising and means that reforestation may not be a simple solution because it may in fact increase disease risk if it leads to further biodiversity loss when forest expansion is made at the expense of grasslands, savannas and open-canopy woodlands [14];
- global interconnectedness, which means an emerging pathogen is increasingly likely to have rapid access to a large number of susceptible hosts, increasing the chances of sparking a pandemic [15].

Focusing surveillance on drivers such as these is attractive because it may give signals at the level of the system when changes are occurring. In addition to achieving early detection to enable early response, this might enable disease to be prevented before it happens by intervening directly in the drivers themselves.

In 2015, Olson *et al.* proposed a new frontier for infectious disease surveillance, focusing on integrated drivers of emerging infectious disease and digital data use [9]. The rationale for this system was to improve risk-relevant information and thereby provide decision-makers with an early alert system at the pre-outbreak stage, and help to tailor interventions at the post-outbreak stage. The authors argued that the latter would benefit from an understanding of the local situational context and underlying drivers, which they sourced mainly from three previous studies on human infectious diseases [16, 17, 18]. Despite mentioning the importance of the human–animal interface and that many infectious disease events were of animal origin, the authors did not explicitly extend these drivers to animal populations, which seems an important oversight. In other health-related domains, multiple additional drivers have been described. A summary of these main drivers across a range of different domains is given in Table I.

Given the large number and diversity of drivers, there is considerable interest in identifying the main drivers to pre-empt specific types of disease emergence and target surveillance accordingly. Semenza *et al.* [11] identified 5 key drivers for infectious disease events out of a total of 17 in Europe, namely: travel and tourism; food and water quality; the natural environment; global trade; and climate. Loh *et al.* [19] demonstrated that transmission pathways varied greatly depending on the primary driver (e.g. vector-borne pathways became more important after land-use changes, and oral transmission was more important after food industry changes) – which shows the epidemiological importance of identifying the key drivers. Zhang *et al.* [23] analysed the relationship between introduced alien (i.e. non-native) hosts and over 10,000 zoonosis events across the globe since the 14th century. They showed that the number of zoonosis events has increased with species richness of alien zoonotic hosts across both geographic space and time [23]. Alien hosts may be introduced to new areas deliberately, such as for hunting, or accidentally, such as in ballast water from cargo ships [24]. Both deliberate and accidental introductions of alien species can be considered as steps on a risk pathway driven by increased global interconnectedness.

Once a disease has emerged, another set of drivers will influence how rapidly it spreads. Perry *et al.* [12] discussed the connectivity of the food systems that create conditions for wide and rapid spread once an outbreak occurs, claiming that concentrated livestock trade increases the likelihood of deep and far-reaching impacts, as seen during the bovine spongiform encephalopathy crisis. This was corroborated by Tang *et al.* [25], who investigated spatio-temporal patterns of live broiler movements between and within provinces in Guangxi in the People's Republic of China and described high-connectivity patterns that could create conditions for rapid virus spread. The authors also showed how networks reacted to price changes and how risk pathways changed accordingly, thereby illustrating the dynamic nature of these drivers.

Economic measures and global capital flows are increasingly being recognised as critical underlying drivers of the health of people, animals, plants and the environment. One such example is financialisation, defined by Bjorkhaug *et al.* [26] as: 'the process through which financial actors, logics, and processes exert increasing influence over economic and social life'. Financialisation has been described as a major influence that shapes all elements of food value chains, including production [26]. While a substantial body of literature has focused on financialisation and healthcare, some authors have examined the wider socio-economic conditions created by financialisation and its effects. For example, Gouzoulis and Galanis [27] looked at socio-economic conditions that prevent social distancing during a pandemic and thereby contribute to disease spread. These authors suggest that, as financialisation leads to worsening housing conditions, financial insecurity in older people due to unsafe pensions, and private debt, it also causes risky public health behaviour, such as indebted employees returning to work while sick. Wallace *et al.* [28, 29, 30, 31] have written extensively about capital flows in global

Table I

Examples of key health- and disease-related drivers grouped by domain

Domain	Drivers
Infectious disease of people [9]	Human susceptibility to infection, climate and weather, human demographics and behaviour, economic development, land use and ecosystem changes, technology and industry, human–wildlife interaction, breakdown of public health measures, poverty and social inequality, war and famine, lack of political will, and international travel and commerce
Emerging issues in animal and plant health [10]	Habitat encroachment and alteration; resource extraction; intensified food production; movement of animals, people and products; changing food production, distribution and consumption – all of these made worse by climate change and human population displacement
Infectious disease threat events [11]	Globalisation and environment, climate, natural environment, human-made environment, travel and tourism, migration, global trade, demographic factors, social inequality, vulnerable groups, prevention, lifestyle, occupational factors, terrorism, healthcare system, animal health, food and water quality, surveillance and reporting failure
Infectious disease of animals [12]	Ecosystem change (e.g. 'deforestation, infrastructure, irrigation, or urban sprawl'), ecosystem incursion (e.g. Lyme disease caused by recreational exposure to ticks), movements of people and animals with more distal drivers being demographic dynamics and higher demand for livestock products, urbanisation, livestock kept nearby in low-income areas (and often in unhygienic conditions), food system connectivity and concentrated livestock
Zoonoses emergence [19, 20]	Land-use change, agricultural industry change, and international travel and commerce
	Increasing demand of people for animal protein, unsustainable agricultural intensification, over-exploitation and use of wildlife, unsustainable use of natural resources negatively impacted by urbanisation, change to land use and mining, oil and gas extraction, travel and transport, food supply chains and climate change
Food system change [21]	Population growth, rise in income, urbanisation and a growing awareness of topics related to diet and health, technological innovation, agricultural intensification, homogenisation, access to infrastructure, urban markets, supermarketisation of food supply, policies enabling national and international trade and internationalisation of private investment
Environmental change [22]	Land-use change, climate change, pollution, natural resource use and exploitation, and invasive species driven more distantly by socio-economic and demographic factors, technological innovation and societal drivers (e.g. culture, government)

livestock agri-business and how dysfunctional economies of scale externalise the negative impact (including disease) to consumers, workers, governments and the environment. This includes the increased vulnerability of people to zoonotic pathogen spillover as austerity programmes undermine public health, and how monoculture plantation, fuelled by private interests, can lead to land use and labour changes that modify interactions between people and animals in favour of disease spillover and spread, exemplified by Ebola [31].

A recent report by the Food and Agriculture Organization (FAO) of the United Nations (UN), the UN Development Programme, and the UN Environment Programme (UNEP) [32] describes how export and fiscal subsidies, as well as import tariffs, are promoting unsustainable practices and distorted food prices, damaging the health of people, animals and the environment, and favouring big agri-business over smallholder producers. Together, these examples show a need to go deeper and look at the underlying processes that shape other drivers – such as structural drivers causing land-use changes, inequality and changed human–animal interactions.

Turning the attention of surveillance away from pathogens and onto drivers

Tempting as it may be to call for the drivers of disease emergence to be prevented (e.g. Kock and Caceres-Escobar [33]), the diversity and global span of many drivers mean that the prevention of drivers is likely to be impossible. Aiming to modify rather than prevent such drivers will increase the likelihood of success. Accordingly, the current authors suggest more attention should be paid to monitoring changes in these drivers of disease emergence. This would include changes in the connectivity of systems that affect the likelihood of disease spread once the pathogen has emerged. In doing so, the scope of what is detectable would be broadened to include known and unknown causes of disease, since *a priori* specification of pathogens would no longer be necessary. Since many pathogens and other health challenges share common drivers that are not population-specific, information on multiple diseases and health risks would be generated from fewer surveillance programmes and thereby promote economic efficiency. The current authors hypothesise that such surveillance would also be cost effective and therefore attractive to policy-makers, but formal economic studies are needed to provide evidence of this.

In the short-to-medium term, the authors suggest drivers be considered on a sector-by-sector basis, to make use of existing structures, data and capacities. They propose that the animal health sector incorporate information on drivers of animal and zoonotic disease into surveillance data. This includes both drivers that are influenced directly by the animal sector and drivers that are animal-relevant but predominantly influenced by other sectors (e.g. activities for human benefit that have an impact on the animal sector). Their selection should be informed by surveillance considerations to generate better knowledge for disease prevention, alert and management.

Table II describes the categories of drivers that could be monitored to capture large-scale changes at the systems level. Drivers are categorised as being proximal if they directly affect health (e.g. the provision of animal-health-related infrastructure and services), or distal if they indirectly affect health (e.g. policy changes such as subsidies or taxes that are intended to change behaviour). This classification is well established in the health sciences, although not without contention [43]. Notwithstanding, the authors consider that both proximal and distal drivers could lead to the necessary conditions for pathogen emergence. For example, a drop in market prices for livestock may lead to producers rearing more animals to recover the shortfall; the resulting increase in stocking density may then be a necessary condition for a pathogen to emerge, spread or cause disease. Importantly, the authors suggest that driver monitoring should focus on the detection of changes in patterns/quantities relating to each driver, as opposed to simply measuring the status quo. This represents a reshaping of surveillance, from the current focus on pathogen detection towards detection and documentation of changes within drivers. This will need to be combined with relevant algorithms to generate alerts, and appropriate decision structures to discuss and use the information produced by the system. Consequently, the primary function will be to generate systems-level, risk-based surveillance information to identify areas where additional attention may be needed from decision-makers and their technical staff/advisors and, over time, to inform the implementation of prevention efforts.

Like other surveillance systems, good knowledge of the drivers will facilitate the design of high-performance (e.g. sensitive, timely) surveillance components. Thus, the data collected will also allow the generation of essential information to better understand drivers and their linkages, and generate new knowledge that can improve surveillance and inform mitigation efforts. This is particularly important in the animal health sector, where there is a dearth of large-scale studies analysing drivers of animal disease. Consequently, decision-makers and technical advisors working in surveillance do not currently know which drivers to prioritise. Additionally, several drivers are general in nature so would need ‘unpacking’ for different animal populations and their characteristics. For example, animal health concerns, trade flows and contact patterns will differ widely depending on the purpose of the animals (e.g. livestock, companion, zoo), the species involved, and the production system in use (e.g. extensive, intensive, backyard).

In the following section, the authors present three case studies from around the world that exemplify the links between drivers and disease emergence. Collectively, these case studies illustrate the need for surveillance of key drivers.

Table II

Examples of proposed drivers of disease that should be monitored by the animal health sector

Driver	Type	Aspects to be monitored	Rationale	Possible data sources
1. Amount, location and species of animals	Proximal and distal	Geo-spatial data on changes in number of animals, density of animals, location of animals, and species composition monitored over time	Time series analysis capturing major shifts in animal populations, including new sites of animal production, concentration, homogenisation and expansion into new habitats	Government Ministries, livestock industry, wildlife population surveys
2. Movements of animals and animal products, and resultant changes to connectivity	Proximal and distal	Changes in animal and product movement data, trade statistics, network connectivity; both legal and illegal	Description and quantification of flows of animals and animal products and changes in network connectivity can show where new trade channels open, and capture cross-border activities at national and international levels	FAOSTAT trade data [34], national (government) trade statistics, government animal movement databases (e.g. TRACES [35]), open-source databases of animal tracking (e.g. Movebank [36])
3. Land-use change	Proximal	Conversion of natural habitats to agriculture, changes within agricultural land use (e.g. intensification of animal production); replacement of grazing with tree planting	Land-use change will alter host species composition and abundance and interactions between species, and thus the potential for pathogen transmission	Government agencies, open-source satellite imagery
4. Location and quantity of animal health-related infrastructure and services	Proximal	Changes in animal markets, feed production processors, abattoirs, animal workers (e.g. slaughterers, official veterinarians), veterinarians, animal health advisors, diagnostic laboratories	Change in the infrastructure and services is an indicator of a shifting system (e.g. a reaction to more animals in an area or a change in production system, or disease, or investment)	Government/private industry/professional association records (e.g. EU-approved food establishments [37], WOAH PVS reports/veterinary workforce surveys [38])
5. Finance and capital flows	Distal	Capital flow data in relation to animal production, asset data (e.g. global corporations), subsidies, tariffs, and private and public investment projects	A change in financing leading to structural changes in the system indicates where shifts may occur in relation to animals (e.g. moving from a diverse system of poultry production to a homogenous, vertically integrated one, or back to a more diverse system; shift towards more extensive production with subsidies favouring biodiversity)	International Monetary Fund balance of payments data [39], investments, private equity and venture capital databases [40]
6. Relevant policy changes	Distal	Subsides and taxes promoting or disincentivising the production or consumption of animal products	Policy changes can be used to alter the behaviour of producers and consumers (e.g. Common Agricultural Policy and import taxes). Recently there has been a proposal to introduce a meat and zoonotic tax to fund pandemic prevention [41, 42]	Government policy documents, national and international data on consumption. Data can be stratified (e.g. urban *versus* rural; local *versus* international)

EU: European Union
FAOSTAT: Food and Agriculture Organization Corporate Statistical Database
PVS: Performance of Veterinary Services
TRACES: European Commission's online platform for sanitary and phytosanitary certification required for the importation of animals, animal products, food and feed of non-animal origin and plants into the European Union, and the intra-EU trade and EU exports of animals and certain animal products
WOAH: World Organisation for Animal Health

Case study 1: agricultural land-use change in the United Kingdom

A major rethink is currently under way in the United Kingdom (UK) to determine how agricultural land can be used to produce food and bioenergy in a more sustainable way [44]. This is primarily being driven by climate change concerns, specifically the need to drastically reduce greenhouse gas emissions and increase carbon capture to limit global warming, alongside the need to produce higher agricultural yields. Such targets will not be achieved without significant changes in land use [45]. The Committee on Climate Change has recommended releasing around one-fifth of agricultural land in the UK for actions that reduce emissions or sequester carbon [46]. This could involve:

- planting 30,000 hectares (90–120 million trees) of woodland each year – a relative increase in forest cover of 30% or about one million hectares over the next 30 years [47, 48]. A recent analysis suggests that two million hectares (one-twelfth of the UK) is potentially available for new woodland [48]. Careful consideration is needed as to how this reforestation will be implemented since the choice of tree species, locations and sizes of land parcels is expected to affect disease emergence risk;
- expanding the planting of energy crops (those grown solely for energy production rather than for food) by 53,000 hectares each year, a relative increase of 750% in land used for energy crops over the next 30 years [47, 49];
- restoring 25–50% of UK peatlands [47, 48];
- reducing the numbers of cattle and sheep farmed by 20%, thereby freeing up land currently used to raise livestock for the other land uses listed above [46].

Such large changes in agricultural land use are likely to bring concomitant changes in the risks of emergence and spread of infectious diseases. This is because land-use changes alter habitats, which affects wild and domestic host abundance and diversity, as well as interactions between species. As a result, surveillance of such land-use changes is needed. The outputs of such surveillance would be useful to inform policies on changes in land use that are currently being formulated in England [50].

Case study 2: pig production in Thailand

In the past few decades, pig production systems in many Asian countries have changed dramatically, with the rise of intensive systems. The advantages of these systems are said to include greater efficiency, productivity, hygiene and biosecurity. The disadvantages include concerns over pig welfare; barriers to entry for smallholders (with effects on their livelihoods), waste production and generation of hazards (e.g. antibiotic residues) [51, 52, 53]. Nonetheless, traditional or backyard small-scale production systems continue to exist in many countries. In Thailand, farms are classified as smallholdings when they have fewer than 50 pigs, but these can be backyard or commercial [54]. In 2018, smallholders constituted 94% of all pig producers, but they only held about 25% of the total pig population [54]. There are key socio-economic reasons for their persistence as they offer sources of income, livelihoods and food security, as well as socio-cultural value [55]. Moreover, industrialised, large-scale farms are expanding rapidly with a growth rate of almost 9% between 2014 and 2018 [54].

Since backyard and small- and large-scale commercial production systems have distinct characteristics, they require different disease prevention, surveillance and management approaches. They also give rise to different forms of disease risk. Consequently, it is important to monitor the landscape of production systems (including types, numbers, locations and their trade channels) to be able to react to changes in these production systems – or, in other words, the changes in conditions that allow pathogens to emerge, spread and cause disease. These changes may be very dynamic, depending on a wide variety of external factors. For example, more smallholders may emerge when other livelihood options dry up (such as hospitality and tourism during the COVID-19 pandemic) or numbers may decrease rapidly when epidemics such as African swine fever hit a country (in which case they may be replaced by other livestock holdings).

In Thailand, smallholders are homogeneously distributed throughout the country, covering all geographic areas [56]. This places demands on infrastructure and the provision of animal health services, and poses challenges for early detection and response. Pig smallholders in Thailand react dynamically and quickly to changes in market prices by adjusting the number of pigs produced; these fluctuations are magnified by disease outbreaks [56]. Formal registration systems may struggle to keep up with these dynamic patterns. Thus, innovation may be required in the way data are collected and analysed to be able to identify changes that may be of epidemiological interest.

Possible avenues may be to monitor local market prices for pigs, market sales and volumes of production inputs such as feed, or market movement data gathered from smartphone applications. Since these same metrics may indicate either an increased risk of disease incursion or the impact of a disease that is already present, any alerts triggered will likely need to be combined with an increase in surveillance efforts and epidemiological investigations, to determine what, if any, additional disease prevention or control action is required.

Case study 3:
animal health surveillance in Tanzania

Tanzania's animal health surveillance is coordinated by the Ministry of Livestock and Fisheries through the Epidemiology Unit of the Directorate of Veterinary Services. To date, this surveillance has tended to focus on understanding disease distribution, the introduction of new strains, risks of disease introduction, and vaccination efficiency [57]. Challenges include the diverse nature of the country in terms of agro-ecological zones and livestock production systems, its interconnectedness with neighbouring countries, and many national parks and game reserves. The latter are home to wild animals that may, in addition to livestock, act as reservoirs of zoonotic disease [58]. Such complex systems have made disease surveillance very expensive and mismatched with Tanzania's budget for Veterinary Services and human resources, which compromises its ultimate goal [57].

To address such challenges, the country is now moving towards the integration of surveillance systems and activities by capitalising on multiple existing sources of data [59], while leveraging technological innovation. Tanzania's current animal health surveillance strategy (2019–2024) advocates monitoring animal health instead of solely focusing on diseases. It has provisions for capturing drivers such as animal movements, rangeland health, antimicrobial purchases and production parameters. New technological interventions to strengthen the capacity of the animal health surveillance system for early detection and response include the introduction of digital surveillance tools and Web-based information systems, such as Event Mobile Application (known as EMA-i); a laboratory information management system (SILAB), AfyaData and an Agricultural Routine Data System [57]. There are also ongoing efforts to make such systems interoperable, while also integrating early warning indicators and alert functions for floods, drought, and unusual migrations of wildlife or movements of livestock that may signal adverse health events. These surveillance information systems may improve interoperability and the data spectrum from community to national level and across sectors, thereby significantly improving early detection. Nevertheless, such intervention has to go hand in hand with strengthening community-level reporting and animal health stakeholder involvement to ensure continuing data generation and use.

Unlike conventional disease surveillance, monitoring multiple drivers and animal health and production parameters implies different data sources, which, in most cases, contain heterogeneous data. Therefore, it will be important to identify and build expertise in fundamental analytical skills in order to make sense of these data and produce efficient systems that can generate signals for early detection and response.

Reshaping surveillance: implications and conclusions

For many years, the field of veterinary public health has protected the health of humans and animals through food safety, zoonotic disease risk assessments and surveillance, and, more recently, antimicrobial resistance monitoring and management. Increasingly, dimensions of environment health are being incorporated to better understand disease emergence, inform mitigation measures, and capture the environmental impact of animal food and feed systems. In the future, a fully integrated One Health surveillance approach incorporating drivers of disease would be expected to bring many benefits, since drivers overlap in their effects and have impacts on the health of humans, animals, plants and the environment (as well as individuals, groups, populations and ecosystems). The authors envisage that focusing on drivers rather than pathogens will generate valuable evidence to inform prevention measures, which could take the form of shaping healthier environments where the likelihood of disease emergence or spillover is reduced. But this is likely to be a massive task that is beyond current capability and so, for now, the authors propose a simpler solution, focusing on selected drivers with direct or indirect impacts on animal health.

In the future, further evidence will become available on the key drivers of health challenges and will inform decisions on what drivers to include in surveillance systems. For example, the One Health High-Level Expert Panel to the Quadripartite (comprising FAO, the World Organisation for Animal Health, UNEP and the World Health Organization) has compiled a list of drivers of zoonotic disease spillover and is now exploring methods to identify where mitigation efforts would make the biggest impact [60].

Many relevant data sets are already available and could be incorporated into driver surveillance. There are national and international databases available on health, disease and related factors, often supported by relevant regulations such as the International Health Regulations, the Codex Alimentarius or the Animal Health Codes. Assessment tools exist to support the development of appropriate health systems, such as the Performance of Veterinary Services assessment. However, new analyses, algorithms, interpretation and decision processes would need to be generated. Such a shift in or expansion of surveillance focus can only work if appropriate resources (human, intellectual, financial) are made available and supported through long-term commitment and the necessary infrastructure and performance (e.g. digital databases, computing power, accessibility and interoperability). Driver surveillance can also take advantage of big data and artificial intelligence. Big-data analytics are used to understand health risks and minimise the adverse impacts of animal health issues by identifying high-risk populations, and combining data or processes that act at multiple scales. Epidemiological modelling approaches and harnessing high-velocity data help to monitor animal health trends and detect emerging health threats [61]. Because of the cross-border nature of many diseases, in addition to cross-border trade and movement patterns, regional collaboration in driver surveillance is likely to be required.

In 2019, a global map of food systems sustainability was published, illustrating how data from multiple indicators could be aggregated into a single output [21]. This approach could act as a blueprint for driver surveillance. Of 192 potential indicators, 27 were chosen spanning four dimensions: environment (including air, water, soil and land, biodiversity and energy); economic (financial performance, employment rate and economic distribution); social (gender equality and inclusion); and food and nutrition (food security, food safety, food waste and use, and nutrition) [21]. The unavoidability of trade-offs was highlighted by the authors and opportunities were emphasised for comparison across geographies, documenting change over time, evaluating progress towards objectives, informing policy strategies and assessing the effects of drivers. This experience suggests that, when designing surveillance for multiple drivers, the animal health sector may look to food systems monitoring to learn about relevant experiences and identify opportunities.

It should not be forgotten that people matter in health surveillance and no one should be left behind or excluded. It is people who shape the systems, people who react to changes in the system, and people who socially construct health [2]. Thus, people need to be central in the surveillance of disease drivers and there may be opportunities for innovation in terms of measuring people's behaviour as proxies for key drivers. The identification and engagement of all stakeholders in a whole-of-society approach and capacity building in health surveillance are essential. This will allow surveillance actors to be more proactive in identifying and understanding the drivers of diseases and other disasters, instead of relying on the reporting of suspicions and clinical signs, which sometimes comes too late. Moreover, the collective public span most environments; they can be a valuable (and economic) source of information. For example, during a recent 'Invasive Species Week' in the UK, river users and local communities were encouraged to look for and report non-native flora and fauna that could be harming the Broads National Park, a regional network of rivers and lakes [62].

As a result of the variety of indicators used, the collation, interpretation and use of all this information will not be straightforward and will require input from a diverse set of professionals. When it comes to policy-making, eventual trade-offs need to be discussed and priorities negotiated; for this to be effective, collaboration will be needed within and potentially across sectors. From One Health experience, it is clear that cross-sectoral surveillance faces many barriers, such as siloed thinking, lack of coordination, unequal representation and power struggles, among others [63]. Thus, it can be expected that a new form of surveillance spanning multiple domains will face similar obstacles. It has been suggested that more and better facilitators for integration can help to promote collaboration, communication and coordination [63].

In conclusion, the reshaping of animal disease surveillance away from its current focus on pathogens and towards the monitoring of drivers has real potential to deliver better results and wider benefits. Because of the co-benefits spanning multiple diseases (both old and new, known and unknown), this approach is expected to be cost effective. Since driver surveillance may give signals at the systems level when changes are occurring, it may even enable disease prevention before outbreaks through direct intervention in the drivers themselves. In due course, the authors envisage a transition from chasing pathogens and recording diseases towards a new focus on identifying and promoting healthy systems.

Refondre la surveillance des maladies infectieuses : moins de chasse aux agents pathogènes et plus de surveillance des facteurs

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Résumé

La surveillance de la santé animale a tendance, malgré son nom, à se focaliser sur la recherche des maladies. Elle implique souvent de chercher les cas d'infection par des agents pathogènes connus (« chasse aux agents pathogènes »). Ce type d'approche exige non seulement beaucoup de ressources, mais elle est aussi limitée par la nécessité d'avoir une connaissance préalable de la probabilité de survenue de la maladie en question. Dans cet article, les auteurs proposent une refonte progressive de la surveillance pour la déplacer au niveau systémique, en se concentrant sur les processus (« facteurs ») influençant la maladie ou la santé plutôt que sur la présence ou non d'agents pathogènes spécifiques. Parmi les facteurs pertinents, on peut citer les changements dans l'utilisation des sols, l'interconnexion accrue au niveau mondial et les flux financiers et de capitaux. Les auteurs soulignent cet élément important : la surveillance devrait se focaliser sur la détection de changements au niveau des schémas ou des quantités associés à ces facteurs. Cela permettrait d'obtenir des informations de surveillance au niveau systémique et basées sur les risques, afin d'identifier les domaines auxquels il pourrait être nécessaire de porter une attention particulière – ce qui informerait, à terme, la mise en œuvre des efforts de prévention. Il est probable qu'une amélioration des infrastructures de données soit nécessaire pour assurer la collecte, l'intégration et l'analyse des données sur les facteurs. Une période de chevauchement permettrait de comparer et de calibrer les deux systèmes (surveillance traditionnelle et surveillance des facteurs). Les facteurs et les liens entre eux seraient également mieux compris, ce qui générerait de nouvelles connaissances pouvant améliorer la surveillance et informer les efforts d'atténuation. Grâce à la surveillance des facteurs, des signaux pourraient être identifiés lorsque des changements se produisent, ce qui constituerait une alerte pour que des efforts d'atténuation ciblés soient mis en place afin d'intervenir directement sur les facteurs eux-mêmes et donc prévenir une maladie avant même qu'elle ne survienne. On peut s'attendre à ce que ce type de surveillance centrée sur les facteurs apporte des bénéfices supplémentaires, puisque les mêmes facteurs peuvent favoriser de multiples maladies. De surcroît, cette orientation axée sur les facteurs plutôt que sur les agents pathogènes devrait permettre de contrôler des maladies aujourd'hui inconnues, ce qui rend cette approche d'autant plus opportune, compte tenu du risque croissant d'émergence de nouvelles maladies.

Mots-clés

Agent pathogène – Facteurs – Maladie infectieuse – Prévention – Santé – Surveillance – Surveillance systémique.

Remodelación de la vigilancia de enfermedades infecciosas: menos persecución de patógenos y más seguimiento de los factores de inducción

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Resumen

La vigilancia zoosanitaria, pese a lo que su nombre indica, tiende a centrarse en la búsqueda de enfermedades, lo que a menudo pasa por tratar de localizar casos de infección por un patógeno conocido («persecución de patógenos»). Semejante método no solo exige cuantiosos recursos, sino que además presenta la limitación de que obliga a conocer de antemano la probabilidad de aparición de una enfermedad. Los autores proponen una remodelación gradual de la vigilancia tendente a dotarla de carácter sistémico y a centrarla no tanto en la presencia o ausencia de determinados patógenos, sino en los procesos («inductores» o «factores de inducción», *drivers*) que favorecen la enfermedad o la salud. Son ejemplo de tales procesos la evolución de los usos del suelo, el creciente nivel de interconexión mundial o los flujos financieros y de capitales. Un aspecto importante que apuntan los autores es que la vigilancia debería tener por objetivo la detección de cambios en las características o cantidades de esos factores de inducción. Ello generaría información de vigilancia basada en el riesgo de carácter sistémico, que serviría para determinar aquellas zonas a las que convendría prestar más atención y, con el tiempo, fundamentar la realización de actividades de prevención. Es probable que la obtención, integración y análisis de datos sobre los factores de inducción exijan inversiones para mejorar las infraestructuras de datos. Si hubiera una fase de solapamiento, sería posible comparar y valorar los resultados de ambos sistemas (vigilancia tradicional y seguimiento de los factores de inducción). Ello serviría para entender mejor los inductores y su vinculación recíproca, lo que generaría nuevos conocimientos con los que perfeccionar la vigilancia y en los que cimentar las actividades de mitigación. Dado que la vigilancia de los inductores puede generar una señal cuando se estén produciendo cambios, señal que a su vez activaría una alerta y propiciaría medidas selectivas de mitigación, podría ser que ello sirviera incluso para prevenir una enfermedad antes de que surgiera, actuando directamente sobre los propios factores de inducción. Cabría pensar que semejante tipo de vigilancia, centrarse en los inductores, puede tener otros efectos beneficiosos, en la medida en que un mismo inductor alimenta la aparición de varias enfermedades. Además, el hecho de centrarse en los factores de inducción, y no tanto en los patógenos, debería servir para controlar enfermedades actualmente desconocidas, por lo que este planteamiento, ante el creciente riesgo de aparición de nuevas enfermedades, resulta especialmente oportuno.

Palabras clave

Enfermedad infecciosa – Factores de inducción – Patógeno – Prevención – Sanidad – Vigilancia – Vigilancia sistémica.

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