Rev. sci. tech. Off. int. Epiz., 2013, **32** (2), 539-548

Integrating the surveillance of animal health, foodborne pathogens and foodborne diseases in developing and in-transition countries

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Summary

Animal diseases, foodborne pathogens and foodborne diseases have enormous impacts upon the health and livelihoods of producers and consumers in developing and in-transition countries. Unfortunately, the capacity for effective surveillance of infectious disease threats is often limited in these countries, leading to chronic under-reporting. This further contributes towards underestimating the effects of these diseases and an inability to implement effective control measures. However, innovative communications and diagnostic tools, as well as new analytical approaches and close cooperation within and between the animal and human health sectors, can be used to improve the coverage, quality and speed of reporting, as well as to generate more comprehensive estimates of the disease burden. These approaches can help to tackle endemic diseases and build essential surveillance capacities to address changing disease threats in the future.

Keywords

Developing country – Emerging disease – Foodborne disease – Infectious disease – International health – Monitoring – Neglected disease – Surveillance – Zoonosis.

Introduction

By 2050, the world's population will reach 9.1 billion. To feed this global population, annual cereal production will need to rise from 2.1 billion tons today to about 3 billion tons and annual meat production by over 200 million tons to reach 470 million tons (12). Since the early 1960s, the consumption of milk *per capita* in developing countries has almost doubled; meat consumption has more than tripled and egg consumption has increased by a factor of five (13). Global meat consumption *per capita* is expected to rise from 41 kg in 2009 to 52 kg in 2050 and from 30 kg to 44 kg in the developing countries (12). Most of the future growth in livestock production (and consumption) will occur in developing countries and in-transition/emerging economies (49).

The global processes of increased international trade, intensification of animal production and major changes throughout many developing and in-transition regions have led to rapid population growth and urbanisation, a transition from low to high-protein food consumption, increasing competition for land and water resources and associated changes in production systems (4, 26). These changes all have an impact upon the epidemiology of animal and foodborne illnesses. The interactions between

agriculture, livestock keeping and poverty are complex and changes in livestock systems present both opportunities and risks for poor households (47), including infectious disease risks associated with livestock keeping and changes in global food systems.

Animal diseases such as foot and mouth disease, swine fever and peste des petits ruminants may not directly affect human health, but can have enormous impacts on food security and incomes. More than 200 human diseases can be transmitted through food (53). The overall burden of foodborne disease is poorly described, particularly in developing countries, but sentinel studies often reveal much larger burdens than previously recognised and significant under-reporting (21, 25, 45). In less-developed countries, food and waterborne diarrhoeal diseases are leading causes of morbidity and mortality, killing an estimated 2.2 million people every year, most of them children (50). In addition, disease outbreaks can lead to enormous economic losses in production and trade income, and can even damage a country's tourism industry (45).

Within the same country, diverse food systems can operate alongside one another: highly sophisticated and well-controlled systems catering exclusively for export markets (as with poultry in Thailand, beef in Argentina and Botswana, poultry and beef in Brazil); systems serving high-end local markets and informal/unregulated food chains linking subsistence farmers to poor consumers and street food outlets. Significant animal and public health risks have been associated with the concentration of intensive production systems next to densely populated urban areas, and areas where livestock populations are raised by small-holders, under extensive production systems, with low levels of biosecurity (16).

The surveillance of animal and foodborne diseases across this range of settings is a considerable task. Effective surveillance systems involve many different institutions and agencies, mandated with promoting human health, animal health, ecosystems, agriculture and food safety. Timely and open reporting and information-sharing among all those involved are crucial to enhance health at the human–animal–ecosystems interface and ensure overall food security. In resource-limited settings, implementing such coordinated surveillance is challenging. In developing countries, large populations are dependent upon livestock, they face enormous endemic disease burdens and are most vulnerable to the various impacts of emerging animal, foodborne and other zoonotic diseases on their survival (36).

In this paper, the authors discuss the surveillance of animal health, foodborne pathogens and foodborne diseases in developing and in-transition countries. They examine the range of people and organisations involved in surveillance, the different points in food production processes at which surveillance can be integrated into the system and some of the tools and approaches that can be used to gather and act upon surveillance data.

Surveillance and reporting in developing and in-transition countries

In much of the developing world, deteriorating government public health services and stagnating or reduced public health and veterinary budgets have crippled disease surveillance and prevention operations, leading to greater vulnerability to disease introduction and spread. Disease reporting is the backbone of any disease surveillance system. Animal, foodborne and zoonotic diseases are often chronically under-reported and many important but under-recognised diseases are therefore considered a low priority, with no significant resources or strategies defined for their prevention and control (21, 31, 45, 51). To address these deficits and target the allocation of resources, barriers that affect disease-reporting behaviour in developing countries need to be better understood and overcome (23, 24, 49).

Livestock keepers are normally the first to identify changes in the health status of their animals and are a crucial link in the chain of disease reporting. Unfortunately, there are disincentives for farmers to report animal diseases: stigmatisation by their peers, financial losses from market exclusion or culling without compensation. Similarly, while the international community fosters transparency in disease reporting, national governments can fear market losses and changes in their disease status which can translate into enormous adverse consequences for the incomes of their farmers, processors and traders, tax revenues and the overall economy (6, 49). Within well-designed surveillance and response systems, there are clear benefits of reporting. Reporting and accessing assistance and advice in the event of disease detection is essential so that sick animals can be treated and prevention and control measures can be implemented. Even when animals are culled as part of a disease control intervention, farmers generally agree to culling if compensation is paid to limit further losses (17, 48, 49). Incentives for reporting often focus on financial benefits, but two-way communication, i.e. feedback to those taking part in surveillance programmes, is crucial in encouraging their continuing support (2, 17, 27, 35). Feedback can include automated responses that confirm receipt of reports, the provision of up-to-date data on drug/vaccine stocks, test results, or a visit by a trained follow-up team (2, 17, 28, 33, 42).

Communications infrastructures are often limited in developing countries and this can constrain the accurate and timely transmission of surveillance data. Electronic data collection and transmission systems can help to improve disease reporting, as well as providing feedback. Mobile-phone-based reporting systems have been extensively used in human health but their use for animal disease surveillance is still relatively under-developed (40). The Infectious Disease Surveillance and Analysis System project in Sri Lanka was one of the first studies to demonstrate the feasibility and acceptability of mobile-phone-based surveillance of animal populations in lower-resource settings (40). The short message service (SMS) Gateway system enabled the Bangladeshi government to receive and respond to reports of highly pathogenic avian influenza (HPAI) sent by community animal health workers (CAHWs) (19). Submitted messages move through a multi-stage chain including veterinarians, laboratory scientists and the Chief Veterinary Officer. Each message is evaluated to identify any required interventions at the farm by rapid response teams, if necessary. Implementation of this system has significantly improved the speed of reporting as well as outbreak detection and response (19).

Telephone hotlines provide opportunities for the general public or individual clinicians to report or receive authoritative information on their health-related queries. South Africa has hotlines for clinicians to discuss suspected human rabies cases (34) and for public queries about H1N1 influenza (43). A new development in transboundary disease surveillance has been the digital pen technology piloted by the Food and Agriculture Organization of the United Nations (FAO) in remote border areas of Malawi, Namibia and Zambia. This technology enables manually recorded paper data forms to be simultaneously recorded electronically. The pen has a built-in digital camera and a Bluetooth connection with a memory chip. Detailed surveillance data can immediately be sent by a field worker to the district or central administration level, using a mobile phone, dramatically increasing reporting speeds (20).

For effective reporting to be possible, there needs to be somebody to report to. The distribution of public and private veterinary service providers varies considerably between and within countries. Most sub-Saharan African countries have vast areas that are under-served by veterinary and para-veterinary personnel. In several in-transition countries, large numbers of veterinarians were previously employed by the government, generally under a centralised system. Today, large parts of these Veterinary Services have been privatised. In many Latin American countries, large numbers of private veterinarians operate in the field, without being integrated into a national surveillance system. By law, they are only required to report officially notifiable diseases.

Intersectoral collaboration

Food production systems involve several interlinked stakeholders from multiple sectors. This creates challenges for effective disease surveillance. Foodborne disease outbreaks can remain undetected because of a lack of communication between the human, veterinary and food sectors (52). The lack of standardised laboratory approaches between these sectors can also hinder the comparability of diagnostic test data generated, reducing the capacity for identifying epidemiological links and transmission pathways (54). Similarly, in some countries there is a separation between the director of Veterinary Services and the laboratory director, leading to a possible disconnection between field veterinary and diagnostic services within the same country. Furthermore, national governments can be reluctant to share data (aside from obligatory reporting), and there is often a lack of understanding among national and sub-national decision-makers and stakeholders about the importance of surveillance (14).

Not only in developing countries but across the world, the timely exchange of information between the different agencies responsible for prevention and control measures (including coherent public communication) and their joint investigation of, in particular, zoonotic and foodborne disease events is crucial (28, 45, 52). Coordinated and integrated disease surveillance and the timely exchange of information across sectors is one of the key components of the One Health approach. To overcome the gap that often exists between the laboratories and epidemiology units operating in the field, FAO, the World Organisation for Animal Health (OIE) and the World Health Organization have piloted the four-way linking framework, a collaborative effort to improve national, regional and global qualitative risk assessment for animal diseases and zoonotic influenza and to enable decision-makers to evaluate the effectiveness of the measures that have been implemented (15).

Stakeholder consultations and priority identification

To enhance cooperation among stakeholders and improve decision-making processes, FAO has developed a consultation process that can be applied within different livestock production chains. Stakeholders include representatives from the government and the private sector (including farmers, processors and service providers), abattoir workers, consumers and scientific experts, including veterinarians, public health specialists and socio-economists. Consultations have been piloted in Ethiopia, Mauritania, Morocco and Vietnam for specific production chains (dairy, dromedaries, small ruminants and swine,

respectively). Through discussion and interaction, the most significant constraints, local priorities and policy options for disease risk management and sustainable development were identified. An important outcome is the realisation that different stakeholder groups have diverging priorities. For example, farmers generally prioritise diseases that have an impact on production, sales and exports, while Veterinary Services emphasise emerging transboundary diseases, and public health authorities and consumers might have other concerns altogether. Understanding the benefits and impacts of disease reporting and control actions on the stakeholders can contribute to more acceptable and effective surveillance systems (17).

Surveillance throughout farm-to-fork pathways

Animal feed

The contamination of animal feed with foodborne pathogens (including toxins and residues) can lead to illness in animals with subsequent effects in humans (8). The rapid and international nature of trade within the food production industry makes feed and food safety a global concern. However, few countries have the capability to inspect and test (legally) imported feed or finished products.

Animal population surveillance

Several important foodborne zoonotic pathogens, such as *Salmonella* spp., *Campylobacter* spp., enterohaemorrhagic *Escherichia coli*, *Toxoplasma gondii* and *Cryptosporidium parvum*, can all be transmitted to humans by asymptomatic animals and their products, which complicates the detection of high-risk individuals or herds (41). Meat inspection is an important point at which animal carcasses can be evaluated for visible changes. However, most pathogens cannot be detected through visual inspection alone and laboratory-based surveillance is therefore essential – although this can be scarce, especially in developing countries (41). Investment in on-site and rapid field tests that are reliable and inexpensive would enhance the early detection of specific pathogens in animal populations along the food processing chain.

Veterinary Services in developing and in-transition countries are frequently understaffed and under-resourced. A limited number of veterinary technicians and, in some cases, CAHWs deliver services in vast and often inaccessible areas, gathering information that can be integrated into disease-reporting systems (30). During the rinderpest campaigns in Africa and parts of south Asia, CAHWs performed important surveillance activities, such as participatory disease surveillance and vaccinating cattle (7). Participatory disease surveillance has recently been adapted by FAO in its work with Ministries of Agriculture and local governments in Indonesia and Egypt to detect and control HPAI in village poultry (11). Since 2010, the scope of these HPAI surveillance teams in Bali has been expanded to also include rabies.

Animal identification systems and movement registers are vital to monitor and retrospectively track disease outbreaks associated with animal hosts, and many export markets demand traceability systems. Botswana is one of the most advanced countries in sub-Saharan Africa in the implementation of animal identification and registration of cattle and has had a computerised system of individual animal identification since 1999 (10). Unfortunately, most developing countries face significant constraints when attempting to implement traceability systems, due to the high investment costs, lack of infrastructure and wide dispersal of the various stakeholders (22).

Abattoir surveillance and meat inspection

Meat inspection procedures were first introduced over a century ago, to detect bovine tuberculosis, parasitic and other macroscopically visible conditions (46). The standards of meat inspection throughout developing and in-transition countries can be very variable. In an Ethiopian survey of routine abattoir inspection for detecting cases of bovine tuberculosis (bTB), lesions suggestive of bTB were detected in 3.5% of carcasses, as compared to 10.1% when more sensitive procedures were applied, and there was considerable variation in detection sensitivity among abattoirs (3). These findings reflect a lack of standardisation of inspection services and differences in the numbers and competence of skilled workers at different abattoirs (3). Economic factors can also influence decision-making processes, since butchers who wish to avoid the financial losses associated with carcass condemnation can attempt to influence the decisions of the meat inspectors (3). For example, in a 2010 study, porcine cysticercosis was detected in over 25% of pigs sampled in villages surrounding Kinshasa (Democratic Republic of Congo) but the parasite was never officially reported (38). In developing countries, a large proportion of animal slaughtering takes place on informal slaughter slabs or at home without any sanitary inspection or recorded findings. These examples show that detailed meat inspection can detect significant proportions of carcasses affected with some diseases, but that a better understanding of the social context within which these inspections are conducted is required, as incentives and consequences are poorly considered. It is important to understand these contexts better to ensure that data are accurately recorded, reported and analysed, to make full use of this wealth of epidemiological information and to promote safer consumption.

Food products of animal origin

Improper and unhygienic preparation and handling of food products is the cause of a high proportion of human foodborne disease (53). In Kampala, Uganda, for example, a survey of milk sellers revealed that 12.6% of informally marketed milk tested positive for *Brucella abortus* by indirect enzyme-linked immunosorbent assay at purchase (29), and high rates of meat contamination with *Salmonella* spp. have been described in Mexico (54). In many developing countries, thorough cooking or deep-frying are traditional practices but changing food habits and the introduction of exotic foods (e.g. raw fish) can pose new health risks for consumers.

Identifying the food product(s) associated with human illness is crucial to enable targeted follow-up and implement appropriate control strategies. Unfortunately, few source attribution studies have been conducted in developing countries. The first application of a source attribution approach to foodborne disease outbreaks reported in Latin America and the Caribbean revealed major changes in the sources of foodborne diseases in this region over time (37).

Human population surveillance

Foodborne illness can be caused by a wide range of pathogens and the symptoms of human infection can vary considerably or be non-specific. The lack of data on the human burden of foodborne disease contributes to the ongoing under-recognition of these diseases and can jeopardise resource allocations (25). Passive surveillance systems are often inadequate because patients with symptoms such as diarrhoea often fail to seek medical attention (54). Syndromic surveillance, the use of existing health data to spot trends and early cases of disease based on clinical signs before formal diagnosis has been confirmed, can be applied in developing countries to help address a range of surveillance questions (32). Syndromic surveillance of foodborne diseases in Egypt and in the Pacific Islands, for example, was able to identify cases despite limited accessibility to diagnostic tests (32). Population-based data on the use of health care, in combination with data from health providers, enabled workers to estimate the incidence of typhoid fever in Egypt (9). Similar techniques, also using laboratory-based surveillance data, have been applied in other cases in Egypt (44), and to estimate the burden of *Salmonella*, *Shigella* and *Brucella* in Jordan (21).

Recent work, using data from 48 countries, indicates that certain non-health variables (e.g. national meat production, the average calorie supply from animal products and the percentage of irrigated land) may also be used, alongside more traditional indicators, to develop broad estimates of mortality attributable to foodborne diseases (25). These techniques may be particularly useful in settings where traditionally used indicators for establishing the human health burden of foodborne diseases are not available (25).

Discussion

Surveillance is essential for countries to identify animal diseases, foodborne pathogens and foodborne diseases, as well as risk factors, to help reduce their impact on animal and human health and environmental contamination. In all settings, effective foodborne disease surveillance requires the direct involvement, close coordination, cooperation, communication and exchange of information between the animal and human health sectors, as well as other sectors involved in the production, transformation and marketing of animals and their products. In developing and in-transition countries, scarce human and financial resources jeopardise the establishment and maintenance of well-functioning integrated surveillance and response systems at the human–animal–ecosystems interface. The capacity and willingness to report disease are closely linked to the ability to access animal and human health services. Disease reporters carefully weigh the benefits and/or negative consequences that can come from reporting diseases and it is important to provide incentives to promote reporting. Efficient feedback on diagnostic test results, the provision of advice and a helpful response, as well as compensation in cases where drastic control measures are put in place, are crucial to maintain the trust of those who report diseases and to ensure their continuing cooperation with prevention and control programmes. The overall scarcity of data on the prevalence and incidence of foodborne zoonoses and their economic impacts greatly hampers the identification of important sources of disease, leading to an inability to design and implement appropriate control measures.

Changing production systems and the adaptation of existing and emerging organisms mean that new approaches must be found to prevent and control the spread of animal and foodborne pathogens. Along the whole production chain, until the food reaches the consumer, hazards and critical control points must be identified and interventions tailored to reduce the risks at each link of the chain. Surveillance and stringent control measures can reduce disease risks and prevent pathogens from moving from the farm through marketing and processing to the consumer. Good agricultural practices, the hazard analysis critical control point (HACCP) approach and good manufacturing/hygienic practices are policies that can identify, reduce and control pathogens along the food chain. In recent years, the emergence of antimicrobial resistance in food-producing animals and humans has been of growing concern. Within this paper, antimicrobial resistance has not been addressed but it is certainly an issue that needs to be taken into consideration when designing surveillance systems and interventions.

Coordinated/multi-pathogen surveillance approaches, in combination with new technologies (e.g bioarrays, pen-side tests) for detection as well as information transmission (e.g. mobile phones, digital pen technology), can reduce the time between sample collection and test results, considerably shortening the possible response time and reducing the risk of further disease spread. Innovative analytical approaches (e.g. developing burden models based on non-health indicators and source attribution analysis) may help to provide data that can be used to highlight the probable burden of foodborne diseases in developing countries, promote greater awareness of the problem and, in turn, prompt efforts to generate data that can be used to tackle the particular foodborne disease problems faced in individual developing and in-transition countries (25, 37).

Foodborne illness is not a single-pathogen problem and, even in developed countries, the laboratory resources and skills to identify pathogens are scarce and aetiology-specific surveillance is often not possible. There are, though, several key interventions that can tackle a range of foodborne disease threats and have cross-cutting impacts upon different pathogens. Basic hygiene and sanitation, access to safe drinking water, latrines and promoting hand-washing before food preparation can all considerably reduce diarrhoeal diseases (5).

Consumers also have an important role to play and they need to be better informed about food safety risks (45). As with disease reporting, consumer hygiene and the introduction of biosecurity at the farm level will only be sustainable if those involved see clear benefits.

What is needed at the local and national levels is also required at the regional and global levels (4). Worldwide increases in the international trade of animals and food products as well as increasing migration and travel are accelerating the spread of pathogens and contaminants in food. One consequence of this increase in interconnectedness is an increased global vulnerability and food safety systems that are becoming ever more interlinked (45). Many diseases that have been controlled or even eliminated in developed countries persist in developing/emerging economies and are often poorly monitored and controlled. By sharing their expertise and resources, countries in developing and developed regions can collaborate to reduce their local disease risks, as well as the universal risks associated with the international transmission of animal and foodborne diseases. By developing coherent international approaches to tackle diseases, countries can develop the core capacities required to address emerging threats, as well as endemic and neglected diseases, and including the detection of unusual disease events (24).

Illustrations of integrated approaches to animal and foodborne diseases in developing countries can be found. In Mexico, the surveillance system for *Salmonella* demonstrates that it is indeed technically and economically feasible to establish integrated food chain surveillance systems in the region (54). In Africa, the Pan-African Rinderpest Eradication Campaign (PARC) integrated epidemiology, risk-based surveillance, participatory disease searching and modelling techniques to detect rinderpest throughout Africa. This campaign was followed by the programme for Pan-African Control of Epizootics (PACE) (18, 19), which aimed at establishing lower-cost national and continental epidemiosurveillance networks for several animal diseases (1). More recently, funds to fight HPAI have further built on the infrastructure developed during the PARC and PACE programmes.

Any kind of surveillance system should not stop at collecting information but include analysis of the collected data and translate these findings into action. Connecting epidemiology units within different Ministries paves the way for compatible surveillance systems which link disease information from the field, the abattoirs, laboratories, hospitals and other points in the chain, and foster coordinated activities, such as joint outbreak investigations, risk communication and recalls. The recent launch of the Zoonotic Disease Unit of Kenya, a collaboration between the Ministry of Livestock Development and the Ministry of Public Health and Sanitation, provides an example of how these links can be formalised (39).

The application of integrated approaches to the surveillance of animal diseases, foodborne pathogens and foodborne diseases envisages the strengthening of all the disease surveillance capacities of all the different sectors involved. In conclusion, surveillance requires long-term investment in cost-effective control measures, by designing flexible integrated systems that can help to tackle existing disease challenges and enhance people's health and livelihoods, while also building long-term capacities to deal with changing and unexpected disease threats.

Acknowledgements

J. Halliday was supported by the Department for International Development, United Kingdom, and by Biotechnology and Biological Sciences Research Council (BBSRC) grant BB/J010367/1 during this project.

La surveillance intégrée de la santé animale, des agents pathogènes d'origine alimentaire et des toxi-infections alimentaires dans les pays en développement et en transition

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Résumé

Dans les pays en développement et en transition, les maladies animales, les agents pathogènes d'origine alimentaire et les toxi-infections alimentaires ont des conséquences désastreuses sur la santé et les moyens de subsistance des éleveurs et des consommateurs. Malheureusement, ces pays disposent souvent de capacités limitées pour exercer une surveillance efficace à l'égard des risques de maladies infectieuses, ce qui aboutit à une sous-déclaration chronique. De ce fait, les conséquences de ces maladies sont sous-estimées et les pays ne sont pas en mesure d'appliquer des mesures de lutte efficaces. Néanmoins, le recours à des outils de communication et de diagnostic innovants, l'utilisation de nouvelles méthodes analytiques et la mise en place d'une étroite collaboration entre les secteurs de la santé animale et de la santé publique permettent d'améliorer la portée, la qualité et la rapidité des notifications, et d'obtenir des estimations plus complètes de l'impact de ces maladies. Ces méthodes peuvent contribuer à lutter contre les maladies endémiques et à mettre en œuvre les capacités de surveillance requises pour faire face aux évolutions futures des risques sanitaires.

Mots-clés

Maladie émergente – Maladie infectieuse – Maladie négligée – Pays en développement – Santé internationale – Suivi – Surveillance – Toxi-infection alimentaire – Zoonose.

Vigilancia integrada de la sanidad animal y los patógenos y enfermedades de transmisión alimentaria en los países en desarrollo o en transición

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Resumen

Las enfermedades de los animales, así como los patógenos y enfermedades que se transmiten por vía alimentaria, ejercen profundos efectos en la salud y los medios de vida de los productores y consumidores de los países en desarrollo o en transición. Lamentablemente, en estos países no suele haber suficiente capacidad para ejercer una vigilancia eficaz de la amenaza que suponen las enfermedades infecciosas, lo que se traduce en una situación crónica de notificación incompleta de los casos. Ello, a su vez, puede hacer que

se subestimen las consecuencias de esas enfermedades y sea difícil aplicar medidas eficaces de control. No obstante, es posible aprovechar la existencia de novedosas herramientas de comunicación y diagnóstico, de nuevos métodos analíticos y de una estrecha colaboración en y entre los sectores de la salud humana y la sanidad animal para mejorar la cobertura, calidad y rapidez de las notificaciones y generar estimaciones más completas de la carga de morbilidad. Esta forma de trabajar puede ser útil para combatir enfermedades endémicas y adquirir capacidades básicas de vigilancia para afrontar en el futuro amenazas sanitarias que evolucionan sin cesar.

Palabras clave
Enfermedad desatendida – Enfermedad emergente – Enfermedad infecciosa – Enfermedad transmitida por los alimentos – País en desarrollo – Salud internacional – Seguimiento – Vigilancia – Zoonosis.

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