Evidence needed for antimicrobial resistance surveillance systems

Cécile Aenishaenslin, a Barbara Häsler, b André Ravel, a Jane Parmley, c Katharina Stärk d & David Buckeridge e

a Research Group on Epidemiology of Zoonoses and Public Health, Faculty of Veterinary Medicine, Université de Montréal, 3200 Sicoitte, Saint-Hyacinthe, J2S 2M2, Quebec, Canada.
c Public Health Agency of Canada, Guelph, Canada.
d SAFOSO AG, Liebefeld, Switzerland.
e Department of Epidemiology, Biostatistics and Occupational Health, McGill University, Montreal, Canada.

Correspondence to Cécile Aenishaenslin (email: cecile.aenishaenslin@umontreal.ca).

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Abstract

One Health surveillance for antimicrobial resistance has been promoted by the scientific community and by international organizations for more than a decade. In this article, we highlight issues that need to be addressed to improve the understanding of the effectiveness of One Health surveillance for antimicrobial resistance. We also outline the evidence needed to support countries planning to increase the level of integration of their surveillance system. Based on experience in Canada and other countries, we argue that more effort is needed to understand and measure the added value of One Health for antimicrobial resistance surveillance and to identify the most effective integration strategies. To date, guidelines for the development of One Health surveillance have focused mainly on the types of data that should be integrated. However, it may be necessary to apply the concept of One Health to surveillance tasks beyond data integration to realize the full value of the approach. Integration can be enhanced across different surveillance activities (data collection, analysis, interpretation and dissemination), taking account of the different expertise and perspectives of experts and stakeholders involved. More research is needed to investigate the mechanisms through which a One Health approach to surveillance can increase the performance of antimicrobial resistance surveillance and, ultimately, improve health outcomes.
Introduction

Antimicrobial resistance is a global threat to human and animal health and has major economic impacts.\textsuperscript{1,2} Antimicrobials are used in animal production to prevent or treat infectious diseases and to promote growth.\textsuperscript{3} The total quantity of antimicrobials used in animals is projected to increase by 67\%, from 63\,151 to 105\,596 tonnes, between 2010 and 2030 due to increasing demand for animal food products globally and to more intensive animal farming practices in several middle-income countries.\textsuperscript{4} The extent to which the use of antimicrobials in animals contributes to the risk of developing antimicrobial resistance in humans at a global scale is unknown. A growing number of studies, however, provide support for causal relationships between antimicrobial use and resistance in animals and in humans at the local and regional scale.\textsuperscript{5} Consequently, surveillance systems that integrate information about resistance of microorganisms circulating in humans, animals and the environment are needed to enhance our understanding of the complex epidemiology of antimicrobial resistance and to inform targeted action. This integrated approach is known as One Health surveillance.\textsuperscript{6} One Health surveillance for antimicrobial resistance has been promoted by international organizations for more than a decade and constitutes a central recommendation of the World Health Organization (WHO) \textit{Global action plan on antimicrobial resistance}.\textsuperscript{7}

To assist countries in the development of surveillance systems, the WHO Advisory Group on Integrated Surveillance of Antimicrobial Resistance released its new guidelines on the application of a One Health approach to surveillance of antimicrobial resistance in foodborne bacteria in 2017.\textsuperscript{8} The report recommends detailed minimal requirements that each country should implement for an effective One Health approach.

In this article, we discuss three important issues that must be addressed to improve our understanding of the global effectiveness of One Health surveillance for antimicrobial resistance and to support countries in the development of such systems. First, we emphasize the need to better understand the mechanisms through which a One Health integrated approach enhances the effectiveness and value of surveillance systems. Second, we argue that more emphasis should be placed on transdisciplinary teams and networks brought together by the One Health approach. Third, we highlight that research
is still needed to develop and evaluate conceptual and analytical tools for measuring the
degree of integration and estimating the effect of this integration on health outcomes.
Each topic is discussed in detail in the following sections. Our views are informed by
ongoing work by ourselves and others that aims to evaluate the added value of One
Health for the surveillance of antimicrobial resistance at the human–animal interface in
Canada, Europe and globally.\textsuperscript{6,9–11} We use the Canadian Integrated Program on
Antimicrobial Resistance Surveillance to illustrate many of our points.

The value of integration
The Advisory Group on Integrated Surveillance of Antimicrobial Resistance guidelines
describe in detail the diverse types of data that should be collected and analysed in a
system for surveillance of antimicrobial resistance in foodborne bacteria.\textsuperscript{8} The guidelines
recommend the collection of standardized and comparable data on antimicrobial
resistance in bacteria from retail food products and humans and, if possible, data on
antimicrobial use in humans and food-producing animals. The guidelines provide
suggestions about which animal species and types of production should be targeted in
relation to the food consumption patterns in the human population and the expected
prevalence of antimicrobial resistance in animal populations. The surveillance system
“may be modified from year to year to capture multiple commodities”. The guidelines
also recommend which bacteria and antimicrobials to consider and stress the need to
include samples from the environment. These recommendations are made with the
implicit assumption that more data are inherently beneficial, without providing strong
evidence about the added value of this approach or any recommendations about how One
Health surveillance systems should be evaluated. Readers of the guidelines are
encouraged to use existing integrated surveillance systems – such as those of Canada,
Denmark, the Netherlands, Norway, the Republic of Korea, Sweden and the United
States of America – as models for the development of new programmes in other
countries.\textsuperscript{8}

Yet, even though these model surveillance systems are all considered to be highly
integrated, their levels of, and approaches to, One Health integration differ in many ways.
For example, the Canadian Integrated Program for Antimicrobial Resistance Surveillance
is operated entirely within a federal public health organization: the Public Health Agency of Canada. The programme collects annual resistance data on three microorganisms that are pathogens of humans (Salmonella spp., Campylobacter spp.) or are sentinel bacteria (Escherichia coli) from three main animal groups (poultry, pigs and cattle). Data are collected at different points along the food-chain, including the farm, the abattoir and retail food stores. In contrast, the Swedish surveillance system divides its operations between the animal and human health sectors. The Swedish National Veterinary Institute operates the Swedish Veterinary Antibiotic Resistance Monitoring programme and the Public Health Agency of Sweden manages the Swedish Antibiotic Utilization and Resistance in Human Medicine programme; the results are published in a joint report. The Swedish system integrates resistance data from several animal pathogens, including from companion animals, and varies the targeted animal species over time. The surveillance systems in Denmark, the Netherlands, Norway, the Republic of Korea and the United States all have different structures and processes, different target microorganisms and antimicrobials, and different points of collaboration across sectors. With such diversity, it may be difficult for countries with little or no experience with antimicrobial resistance surveillance to identify priorities and to construct an informed development plan to establish an integrated One Health surveillance system. Moreover, despite years of experience with One Health surveillance in several countries, evidence is still lacking that the performance and cost–effectiveness of highly integrated surveillance systems are better than less integrated systems. We therefore conclude that there is a need to move from generic guidelines for One Health integration to empirical evidence that can guide the design of surveillance systems. To produce such evidence, research is needed to assess the added value of existing One Health surveillance systems for antimicrobial resistance.

**Designing surveillance systems**

In the Advisory Group on Integrated Surveillance of Antimicrobial Resistance report, integrated surveillance of antimicrobial resistance in foodborne bacteria is defined as “the collection, validation, analyses and reporting of relevant microbiological and epidemiological data on antimicrobial resistance in foodborne bacteria from humans,
animals, and food, and on relevant antimicrobial use in humans and animals." This definition tends to reduce the concept of One Health to integration of data sets from different sources: humans, animals and food. Apart from recommendations on the types of data that should be collected, the report presents some examples of integrated analysis and reporting formats. However, there is no clear guidance on other essential dimensions of One Health systems, such as intersectoral collaboration and information sharing.  

Collecting data from humans, animals and the environment is crucial to the concept of One Health and constitutes an important first step towards an integrated approach. But the interdisciplinary nature of One Health surveillance generates outcomes that go beyond the value of information produced from integrated data collection. Also, to capture the added value of One Health surveillance, we need to revisit how we characterize and measure the integration of a surveillance system. In Table 1, we illustrate how One Health integration applies to all activities of a surveillance system from data collection to analyses, interpretation and dissemination. In each activity, integration can be achieved at different points and to differing extents in terms of the type of data integrated; the operations and processes used to integrate the data; and the collaboration of stakeholders that are implementing or benefiting from the activities. The level of integration can therefore be conceptualized, measured and increased for each surveillance activity.

At the level of data collection, integration can be increased by sampling from different animal species, production types, points along the food-chain, locations in the environment and species of microorganisms; and according to risk factors. For example, the Canadian Integrated Program on Antimicrobial Resistance Surveillance has increased its level of integration gradually over the years by adding collection points along the animal production system. The programme started by integrating data on antimicrobial resistance from animal samples collected at abattoirs with data on antimicrobial resistance from sick animals and humans. Over the next 15 years the programme added other type of data, including antimicrobial resistance of organisms in farm samples and in retail meat samples from different provinces, and the use of antimicrobials both in animal production and human health.
Integration can also be increased by harmonizing sample and data analyses methods across sectors to enhance the comparability of the information produced; or by centralizing surveillance operations related to data collection across one or more institutions. At the level of data analysis and interpretation, integration can be enhanced by moving from simple comparisons of trends between animal and human data sets towards multivariable analysis that, for example, controls for the effect of different risk factors. Moreover, One Health integration can be increased by including multiple disciplines in the analyst team. For example, the Canadian programme team is composed of epidemiologists and experts in avian, swine and bovine medicine as well as public health. This One Health team is key for analysis and interpretation of the surveillance information in context, and for the dissemination of surveillance information to a broad and multidisciplinary network of end-users.

At the level of information dissemination, integration can be increased by moving from producing different reports for each animal species to integrating all surveillance information into a joint report, and by increasing the multidisciplinary nature of the network that is reached by these dissemination products. The Canadian programme team engages with over 600 stakeholders with expertise in animal and public health. Those involved include livestock and poultry producers; veterinary physicians; physicians and their licensing bodies; local, provincial and federal public health and animal health organizations; pharmaceutical organizations; drug and food regulators; animal and farm advocacy groups; and researchers. These stakeholders are invited to discuss integrated information on antimicrobial resistance at events such as the annual stakeholder’s meeting of the Canadian Integrated Program on Antimicrobial Resistance Surveillance. The One Health network of stakeholders would not be able to exchange views and information to the same extent without the support of the Canadian programme team. Consequently, the surveillance team and its network of engaged stakeholders are essential to ensure that the information is used for decision-making and for inducing change in the use of antimicrobials in animal and human populations. Hence, we propose that the team and its network can be seen as direct contributors to the effectiveness of the One Health surveillance system (Fig. 1).
Integration in data analysis, interpretation and dissemination are important points in the design of effective One Health surveillance systems. We have developed a semiquantitative scale, based on our experience in the Canadian programme, to systematically measure the level of integration in antimicrobial resistance surveillance systems for foodborne bacteria. The scale comprises the elements that can be integrated in each surveillance activity, as we have already described, and proposes six levels of integration that can help to characterize One Health integration (Aenishaenslin C et al., Faculty of Veterinary Medicine, Université de Montréal, unpublished data, 2018). We hope that our scale will become an essential step in evaluating the effectiveness of One Health surveillance systems and serve as a guide for countries in the process of increasing the level of One Health integration within their surveillance system.

Evaluating the added value

A greater level of integration in a system does not necessarily result in a more effective or more cost–effective system. Over recent decades, several generic frameworks for evaluation of surveillance systems in human and animal health have been developed by different researchers and organizations. The surveillance evaluation frameworks in both the public and animal health sectors propose groups of attributes that can be assessed as indicators of the effectiveness of a surveillance system, such as acceptability, data quality, data sensitivity, timeliness and cost–effectiveness.\(^\text{19–21}\) In line with these frameworks, researchers have used economic analysis to estimate the added value of One Health surveillance, although not to examine integrated surveillance of antimicrobial resistance.\(^\text{22–25}\)

The value of One Health surveillance for antimicrobial resistance can be conceptualized and measured across a spectrum of different outcomes that can be classified as (i) immediate; (ii) intermediate; or (iii) ultimate (Fig. 1). Immediate outcomes include increased understanding of the antimicrobial resistance epidemiology at the interface across human health, animal health and the environment; the value of this knowledge is in the intellectual or social capital that is generated.\(^\text{23}\) Intermediate outcomes include changes in policy or behaviours resulting from surveillance information; the value in this case is in the size of the reduction in antimicrobial
resistance that results from these changes. Only for the ultimate outcomes – improved animal, human and environmental health – can tangible benefits be measured directly in an economic evaluation. Hence, the benefits resulting from changes in the occurrence of disease in animals and humans can be attributed to decisions about interventions to mitigate the effect of disease (or decisions not to intervene) that were implemented because of surveillance outputs.\textsuperscript{23,24}

Other researchers have conceptualized the objectives of One Health surveillance according to the epidemiological status of a disease within three stages of action to mitigate the disease: (i) sustainment; (ii) investigation; and (iii) implementation.\textsuperscript{26} The sustainment stage is when the disease incidence is at an acceptable level and mitigation efforts aim to keep the incidence under a certain threshold. In the investigation stage, the incidence goes over the acceptable level and the mitigation activities aim to collect the indicators (prevalence, morbidity, mortality, risk factors, etc.) that are necessary to identify the best points of intervention. Finally, in the implementation stage, the intervention is identified and implemented, while surveillance aims at evaluating its effectiveness.

Antimicrobial resistance is a complex and, for many countries, a relatively new concern. Surveillance information is therefore often not yet linked to planned interventions and the objectives of antimicrobial resistance surveillance mainly correspond to those in the investigation stage. The investigation stage can be maintained for years, as the complexity of the antimicrobial resistance epidemiology complicates identification of the most cost–effective interventions. Also, other types of changes that would lead to a reduction of antimicrobial resistance in animals, humans and their ecosystems, such as changes in policies and behaviours, are influenced by external factors such as the political context (Fig. 1). Consequently, evaluation of the added value of One Health surveillance for antimicrobial resistance poses methodological challenges. An important step that has been neglected so far by researchers and public health practitioners is the evaluation of whether and how One Health approaches impact policy and behaviour changes. Mixed methods and qualitative methods, for example in policy analysis, should be considered to help understand how information produced by the surveillance system is used by different stakeholders and decision-makers.
Conclusion
Countries developing One Health surveillance systems need empirical evidence about how to achieve integration in a cost–effective manner. Research on how the performance of One Health surveillance systems for antimicrobial resistance are influenced by different levels of integration is important for generating evidence and for benchmarking and recommending best practices.

Evidence about the added value of One Health surveillance systems is also important for effective implementation of the global antimicrobial resistance surveillance system. The system was launched in 2015 by WHO to standardize antimicrobial resistance surveillance across countries and help support the implementation of the global action plan on antimicrobial resistance. Up to now, the global system has focused on developing national surveillance systems able to produce information on antimicrobial resistance in humans that can be compared across countries. The global system also aims to support countries in moving towards surveillance systems capable of integrating data on antimicrobial resistance in animals. Countries will need evidence-based guidelines to structure the development of effective and efficient integrated surveillance for antimicrobial resistance. In addition, harmonized evaluation approaches and tools that are adapted to the complexity of One Health surveillance systems should be developed, integrated into the global antimicrobial resistance surveillance system and promoted at the international and national levels.

Evaluating the added value of One Health approaches for antimicrobial resistance surveillance is not a simple task, but it should not be set aside because of its complexity. We underline the need to better define and evaluate the components of One Health integration in antimicrobial resistance surveillance systems. Collaborations among One Health surveillance teams and their networks should be more carefully integrated in the design and evaluation of antimicrobial resistance surveillance systems and should be better addressed in guidelines provided by international organizations.

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Competing interests:
None declared.
References


Table 1. **Types of integration in a surveillance system for antimicrobial resistance in foodborne bacteria by surveillance activities**

<table>
<thead>
<tr>
<th>Surveillance activity</th>
<th>Integration of information</th>
<th>Integration in operations and processes</th>
<th>Integration of multiple institutions, disciplines and perspectives</th>
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</table>
| **Data collection**     | Integration of antimicrobial resistance data from:  
  - human, animal and environmental sources;  
  - different animal species;  
  - different production type within a species (for example organic versus other productions)  
  - different collection points (farm, abattoir, retail meat, water, soil);  
  - different microorganism species;  
  - different antimicrobials; and  
  - active and passive surveillance activities  
  Integration of data on antimicrobial use and other risk factors (e.g. farm management practices)  
| Use of more complex integrated statistical analysis (versus simple comparisons of trends in data from different sources)  
| Standardization across human and animal sources of:  
  - laboratory methods for samples; and  
  - measurement units used to analyse and report antimicrobial resistance and antimicrobial use  
| Integration of:  
  - data collection in one local or national organization (versus multiple organizations involved in animal health and human health); and  
  - sample analysis in one laboratory (versus different laboratories for animal health, human health or others)  
| **Data analyses and interpretation**  
Comparisons of data on antimicrobial resistance and antimicrobial use from:  
  - human, animal and environmental sources;  
  - different animal species;  
  - different animal commodities;  
  - different collection points;  
  - sick and healthy animals and humans;  
  - different geographical locations; and  
  - over time  
Analysis of the links between antimicrobial use, other risk factors, and antimicrobial resistance  
| Analysis of relationships in antimicrobial resistance trends:  
  - across data from different sources; and  
  - in relation to risk factors  
| **Surveillance information dissemination**  
Integration of information from different sources in reporting activities (versus separated by sources)  
| Reporting:  
  - using one main harmonized format for animal health and human health end-users (versus multiple formats);  
  - at the same time to human and animal health stakeholders through at least one activity (one report or one meeting); and  
  - adapted to stakeholders from human and animal health (other reporting activities)  
| Dissemination of information:  
  - coordinated by one institution (versus different institutions in charge of dissemination); and  
  - based on the perspectives of experts in different disciplines and the stakeholders involved in dissemination  

*a Includes sample collection, sample analyses and data centralization.*
Fig. 1. Logic model of a generic One Health surveillance system for antimicrobial resistance

Notes: The logic model illustrates the relationships between immediate, intermediate and ultimate expected outcomes of One Health surveillance. The arrows on the left present the growing strength of influence of external factors in achieving more distal outcome.