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Integrated surveillance for antimicrobial resistance: challenges and directions

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Summary

Integrated surveillance for antimicrobial use and antimicrobial resistance in the context of One Health is surveillance based on systemic, cross-sectoral, multi-stakeholder perspectives that inform decisions on actions to reduce antimicrobial resistance, with the aim of keeping antimicrobial agents effective for future generations. Despite broad advocacy, this type of surveillance is mainly in place in high-income countries. This article gives an overview of the state of knowledge on integrated surveillance for antimicrobial use and resistance at global, regional and national levels, presents its value proposition, provides specific examples, and discusses gaps, challenges and future directions.

Keywords

Antibiotics – Cross-sectoral – Integration – Monitoring – One Health – Resistance – Surveillance systems.

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Introduction

The Global Action Plan on Antimicrobial Resistance, published by the World Health Organization in 2016, called for implementation of national action plans on antimicrobial resistance (AMR) in all countries and recommended development of integrated surveillance systems. At the time, the justification for developing such systems was based mainly on the experience of pioneering countries, such as Canada and Denmark, with established surveillance systems that integrated AMR and antimicrobial use (AMU) data from different sectors. These integrated systems have indeed been very successful and have led to changes in practices and policies aimed at reducing AMU and AMR, mainly to protect human health [1,2]. Apart from several examples in high-income countries, and a growing number in low- and middle-income countries (LMICs) such as Nepal [3], Sierra Leone [4], Sri Lanka [5] and Thailand [6], there is limited evidence to define and support good practices for building and maintaining integrated AMR and AMU surveillance systems.

Over the past decade, multiple efforts have been made in various countries to strengthen sectoral surveillance systems, develop national action plans for AMR and promote surveillance integration. Important progress has been made in defining what is meant by integrated surveillance for AMR and AMU, in identifying and documenting the added value of integrated compared to non-integrated systems, and in developing tools to support countries and organisations in implementing, managing and evaluating such systems.

The aim of this article is to summarise the state of knowledge about integrated surveillance systems for AMR and AMU by i) summarising what is known about their general characteristics and added value; ii) describing the current state of integrated surveillance initiatives for AMR and AMU at national, regional and international levels, including gaps and challenges; and iii) discussing some avenues for further development of integrated surveillance systems for AMR. As AMU surveillance is considered a component of integrated surveillance for AMR, the term integrated surveillance for AMR is used in this article to refer to systems that integrate AMR with or without AMU data from different sectors (e.g. human, companion animal, livestock production, crops and environment). The article focuses on structure, governance and economic aspects of integrated surveillance systems. Other technical elements essential to AMR surveillance, including what microorganisms and antimicrobial agents are selected, laboratory capacity and availability of diagnostic methods, and what AMU metrics are used, are not covered. These topics are discussed in other articles of this issue of the *Scientific and Technical Review*.

Conceptualising integrated surveillance systems for antimicrobial resistance and use

Although the term 'integrated surveillance' is increasingly used in grey and scientific literature, there is still no consensus on its definition, either generally or in the context of AMR. However, most proposed definitions recognise that this type of surveillance brings together data from multiple sources and sectors and requires strong cross-sectoral collaboration and technical capacities [7,8]. This article refers to the definition proposed by the international CoEvalAMR consortium, which defines integrated surveillance for AMR in the context of One Health as surveillance based on systemic, cross-sectoral, multi-stakeholder perspectives that inform decisions on action to reduce AMR, with the aim of keeping antimicrobial agents effective for future generations [9]. Consequently, integrated surveillance supports the policy cycle of AMR prevention and management by informing problem identification, agenda setting, policy development, implementation and evaluation.

Through the systematic collection and analysis of data from different sectors and populations and the associated sharing of information and interpretation by various stakeholder groups, integrated surveillance for AMR allows documentation of AMR and AMU trends over time and detection of new occurrences of resistance. It can also provide evidence on whether policies and interventions have achieved their intended effects and help determine the need for and best target of future interventions. However, because the context is different for every country, diversity exists in how these integrated systems are designed and implemented, both in terms of their scope and objectives and in terms of operational and governance structures. The main objective of most integrated surveillance systems described in the literature is to follow trends in antibiotic resistance levels across different species/sectors and to detect emergence of new resistance genes or resistant bacteria. Antiparasitic, antiviral and antifungal resistance are rarely included in official surveillance systems. Moreover, most systems generate trend data to develop and evaluate strategies to combat AMR and to increase awareness and knowledge about AMR among consumers and health professionals [10].

In integrated surveillance, integration often refers to the gathering and combining of data from different sources, including animals and humans, foods of animal origin (i.e. milk, eggs and meat) and, more rarely, the environment and foods of plant origin. However, integration is about more than data. A scoping review describing the characteristics of integrated surveillance systems for AMR proposed two integration dimensions: information integration and structural integration [10]. Information integration refers to the system's ability to combine information from various commodities or populations, collected at multiple points, and involving diverse microorganism species with a range of pathogenicity and resistance profiles. The data are often collected for different reasons, using different surveillance strategies and various laboratory methods, which presents challenges when attempting to integrate them (e.g. combining phenotypic and genotypic data). Some countries have databases and systems in place that allow data sharing; others may not be able to share data but can exchange the resulting information, such as through formal reports, cross-sectoral committees or other coordination structures. Such information sharing will benefit from structural integration, which refers to the collaborative mechanisms used to operationalise and govern the system (steering, coordination, and technical and scientific support) and to implement specific surveillance activities (data collection, management, analysis, communication and dissemination of surveillance results) [11]. Structural integration may include, for example, the establishment of inter-sectoral and interdisciplinary committees responsible for prioritising surveillance activities, jointly interpreting data or information in context, or disseminating results to the appropriate decision-makers.

These two integration dimensions are not independent of each other, as information integration requires well-established structural integration [10]. For example, a study carried out by Aenishaenslin *et al*. [7,12] in collaboration with the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS), suggested that the extent of integration can increase not only by adding data sources from new sectoral components (e.g. adding data on AMU or AMR in animals or from the environment to human data), but also by changing how these data are analysed (e.g. together *versus* in parallel), by whom the analysis outputs are interpreted (e.g. a multidisciplinary team *versus* a single epidemiologist), and to whom the results are disseminated (e.g. to a specific sector *versus* multiple sectors and institutions) (Fig. 1). In the same study, the authors suggested a semi-quantitative measurement scale to characterise the level of integration of surveillance systems for AMR that can help guide further development. Importantly, greater integration in surveillance is not always more efficient or desirable, as greater integration may be associated with increased resource consumption and significant human resource efforts – at least in the short term. The main challenge is to find the right level of integration to best achieve the desired outcomes [13].

Existing initiatives at national, regional and international levels

A recently published scoping review identified 14 operational and well-documented national integrated surveillance systems for AMR, all implemented in high-income countries (Table I) [10]. Several explanations for the overall low implementation of such systems were identified, including technical, budgetary and institutional constraints. As the AMR problem and its complexity are framed differently depending on the country, efforts to increase integration in national AMR surveillance programmes vary substantially across the globe. For example, Thailand has conducted integrated surveillance for AMR since 2017 [6,14], while in India the AMR issue seems to be considered mainly within the healthcare sector and cross-sectoral initiatives receive little support [15].

LMICs face additional barriers to surveillance integration. Political instability, weak enforcement of regulations and lack of resources are not conducive to the establishment of effective sectoral surveillance, and even less to inter-institutional mechanisms necessary to implement integrated surveillance [10]. In many LMICs, surveillance may be limited to one-off epidemiological surveys, mainly conducted by research institutes with access to external funding and rarely used for decision-making [16]. In this time of polycrises, AMR is not among the top priorities for many governments, compared to other issues with a perceived higher societal importance, such as geopolitical instability. Moreover, other health challenges with more immediate and visible socio-economic impacts than AMR are often preferentially supported by donors [10].

Well-documented surveillance systems with high levels of integration include the Danish Integrated Antimicrobial Resistance Monitoring and Research Programme (DANMAP) and CIPARS, which are used as examples in this article. DANMAP was established in 1995 and CIPARS in 2002. Both are national, government-coordinated surveillance programmes dedicated to the collection, integration and analysis of data about AMU and AMR in humans, domestic animals and animal-derived food sources [8,17,18]. The broad scope of both programmes enables investigation of trends and associations between AMU and AMR whereby targeted and meaningful actions can be implemented. However, neither programme routinely integrates data about AMR in the environment [18,19].

At the global and regional levels, several integrated surveillance initiatives have been implemented (Table II). These are commonly led by international organisations that have a global or regional reach. It is not a requirement that surveillance be publicly done, although few initiatives are funded – fully or partially – by private companies. Most of the listed initiatives are aligned with the mandates of the lead organisation, focusing on human or domestic animal health. Information resulting from these surveillance efforts is regularly and publicly reported in annual reports, which also provide insights into the progress and functioning of these initiatives. Although these initiatives require collaboration across countries for the reporting of AMR and/or AMU data, true integration across sectors is rarely carried out beyond the country level.

Current state of knowledge on the added value of integrated surveillance systems for antimicrobial resistance

The added value of integrated surveillance systems for AMR lies not only in their capacity to generate and analyse comparable data across sectors, but also in their ability to support more effective changes in practices and policies aimed at mitigating AMR and preserving the effectiveness of antimicrobial agents for humans and animals [20]. Although empirical evidence of this added value is still limited, progress has been made in conceptualising and conducting relevant evaluations. A basic conceptualisation of One Health integrated surveillance and the associated business case was proposed by Queenan *et al*. [20]. A few years later, a generic logic model was developed for integrated AMR surveillance systems, based on existing literature and short-, medium- and long-term outcomes reported by CIPARS stakeholders [8]. Building on this logic model, an associated conceptualisation for quantitative economic evaluation was proposed with a focus on the links between surveillance, information, integration and intervention [21].

The logic model has been used to evaluate CIPARS, including stakeholder collaboration, its One Health-ness, and its costs and benefits [19]. Results showed CIPARS influences policy and practice and generates significant economic and intangible benefits, even when considering only benefits for the human health sector. In the early 2000s, CIPARS identified a strong link between third-generation cephalosporin resistance in *Salmonella enterica* serovar Heidelberg from humans and from retail chicken [22,23]. These findings prompted the poultry industry to reduce AMU gradually, and beginning in 2014, a sustained decline in chicken and human non-typhoidal *Salmonella* infections resistant to third-generation cephalosporins was observed [24]. Based on these outcomes, Mediouni estimated a benefit–cost ratio ranging between 2.3 and 10.9, with returns on investment up to 995% [19]. Intangible benefits included increased trust and cooperation through sustained communication, improved human capital through cross-sectoral skills development and knowledge sharing, and increased consumer confidence in food safety [19].

Another study evaluated the performance and value of the integrated surveillance system for AMR in England. Through semi-structured interviews with stakeholders from the human, animal, food and environment sectors, the researchers highlighted the benefits of this system in generating new knowledge about AMR across sectors but also recognised that the use of this information to guide concrete action was limited [9]. The same group of researchers assessed the cost-effectiveness of integrated AMR surveillance in the United Kingdom and an associated strategy to mitigate livestock-associated methicillin-resistant *Staphylococcus aureus* (LA-MRSA) as a case study. The counterfactual was a situation of not having the integrated surveillance; the effect was measured in human LA-MRSA cases avoided (expressed as disability-adjusted life years avoided). The integrated AMR surveillance strategy was found to be both cost-saving and more effective compared to using a non-integrated approach [21].

Along these lines, a study investigated factors that facilitate collaboration between AMR surveillance initiatives in France by interviewing programme coordinators and experts. Several benefits of collaboration were reported, including increased efficiency through the pooling of resources and expertise, as well as increased trust and stronger relationships between coordinators [25].

Some of the regional and international programmes reported in Table I have been subjected to assessments or commentaries by external researchers and stakeholders. In contrast, economic evaluations of surveillance initiatives beyond national level have not been conducted. The current state of knowledge on the added value of integrated surveillance for AMR reflects the difficulty in measuring outcomes and benefits [26]. To conduct full economic evaluations of integrated surveillance, it is necessary to have data on how the surveillance information is linked to interventions and the effects of the intervention. However, formal data collection covering all costs and benefits systematically as part of monitoring, evaluation and learning efforts does not usually take place. Benefits of such systems tend to be long-term and disjointed from the data collection and reporting cycle. It is also difficult to assess the contribution of surveillance to the observed outcomes and impacts because i) other data and events also influence outcomes and ii) the systems are frequently updated to respond to changing methods and circumstances, which complicates the design of a cost–benefit study. Furthermore, the beneficiaries of integrated surveillance may be stakeholders without direct involvement in surveillance activities or data provision. Consequently, they may not be accounted for, even in comprehensive evaluations, which suggests that the added value is probably systematically underestimated.

Gaps and emerging issues

In addition to the lack of evidence on the added value of integrated surveillance systems in different contexts, several gaps and issues remain regarding their implementation. These gaps and issues are divided here into two broad categories: i) what is under surveillance (or not) and ii) how surveillance is conducted (Fig. 2).

When considering the multiple drivers of AMR in a One Health context, one might wonder whether the data currently collected by most integrated surveillance systems are able to identify the right levers for action and measure whether implemented actions work. Several factors considered important to the AMR crisis are rarely included in existing surveillance systems, such as the environment (both as a source of resistant organisms and as a pathway of transmission between sectors) and human behavioural factors, in particular those that determine whether, when, which and how much antimicrobials are used in human and veterinary medicine and in agriculture. These factors and others that contribute to AMR in the food chain have been described in several different contexts (e.g. [27,28]). What remains unknown is how best to incorporate data about these broader system elements into existing integrated surveillance structures.

Most surveillance systems only collect data to monitor changes in the proportion of isolates that are resistant to a range of antimicrobials in selected microorganisms of importance mainly to human health, and sometimes to animal health. These data are crucial but often are measured only once resistance has occurred at detectable levels. This makes it difficult to appropriately target sustainable and effective actions to prevent, and not only mitigate, the development and spread of new resistance genes and resistant microorganisms. Some systems capture or generate data on AMU, but this is not necessarily done systematically or at a sufficiently detailed level, and most often antimicrobial sales data, not use data, are included [29]. Moreover, most surveillance systems do not routinely integrate AMU and AMR data beyond generating simple correlations or placing AMU and AMR data together in a single figure. This lack of integration increases the difficulty of identifying prescribing and usage practices that contribute most to the development of resistance, information that is needed to take early preventive action. New methods and tools to effectively analyse AMU, AMR, drivers and impacts are needed.

A major critique of integrated surveillance for AMR in a One Health context is the lack of inclusion of environmental data. Existing initiatives collect some data from environmental settings such as the agricultural environment. These data are rarely included in official surveillance reports but can be accessed through occasional research publications (e.g. [30]). Recently, new methods have been developed and applied to use sampling of waterways to detect and predict changes in infection levels in different communities and agriculture. In Denmark and elsewhere, experience is being gained from ongoing use of these new methods, focusing first on measuring viruses and then on AMR in wastewater [31]. However, it is important to recognise that wastewater surveillance mainly provides information on what is circulating in human populations and does not help understand changes in AMR circulating in broader ecosystems, which is still a major surveillance gap across the world. Identification of harmonised detection methods for AMR in waterways is still required before it will become part of surveillance systems such as DANMAP [A.R. Larsen, personal communication, 2025]. The benefits of including more environmental AMR components in existing surveillance systems need to be assessed relative to the costs for additional sampling, testing and analysis.

While progress has been made in defining, characterising and evaluating integrated surveillance systems for AMR, there is limited evidence on how to effectively govern such systems. Governance involves coordinated strategies, norms and procedures across sectors, ensuring inclusivity and shared decision-making. Effective One Health governance must engage political actors to align policies, resources and knowledge across human, animal and environmental health domains. Moreover, it should foster transdisciplinary and cross-sectoral collaboration at both local and global levels. Ruckert and colleagues [32] identified six domains that need to be taken into consideration in the governance of integrated surveillance systems: participation, coordination and collaboration, management, sustainability, accountability and transparency, and equity. These dimensions should be considered when designing and evaluating a surveillance system. To date, these dimensions have rarely been formally evaluated.

Some LMICs have made substantial progress in developing suitable surveillance systems, and many LMICs have received strong support from technical and financial partners to develop their systems, mainly through capacity building and establishment of intersectoral governance mechanisms [33-35]. Some LMICs may have proposed policy and operational solutions to integrated surveillance that they know would be attractive to donors, in line with the integrated surveillance models advocated by international organisations. However, these solutions might not be feasible unless they have been adapted to the specific country's needs and priorities, including the national capacity. This is a good example of equity issues arising from the international call for integrated surveillance for AMR.

Advancing integrated surveillance for antimicrobial resistance

Integrated surveillance systems may either be established as integrated systems, like DANMAP and CIPARS, or emerge through gradual, stepwise integration of already-robust sectoral surveillance systems. The Quadripartite Guidance for One Health Integrated Surveillance of AMR and AMU promotes flexibility: countries should plan sector-specific surveillance activities in consultation with other sectors, even at the earliest stages of development [36]. While there is a compelling case for integrated surveillance for AMR, its creation comes at a cost that stands in competition with other resource requests and decisions. Thus, foundational work – such as mapping existing systems, characterising gaps and understanding sectoral priorities combined with a business case – is recommended before deciding how to advance regarding establishing integrated surveillance programmes. Countries need to identify where their problems lie in AMU and AMR, assess what improvements are feasible and cost-effective, and determine which actors are motivated to generate, analyse and use the data for decision-making. This information can then shape tailored surveillance strategies with real-world and local utility.

The investment landscape for AMR is changing as more evidence is produced and advocacy and resource mobilisation efforts take effect. At the 79th UN General Assembly High-Level Meeting on AMR, global leaders committed to specific targets and actions and requested US$ 100 million in catalytic funding and sustainable country financing [37]. While there has been a steady increase in public and philanthropic funding for AMR [38], the current geopolitical context has led to large-scale cuts in international aid and changes in funder structures that are posing substantial challenges for the work on preventing AMR, including surveillance. Innovative financing mechanisms with multi-partner set-ups and blended contributions may offer a way forward to invest in national action plans and innovation pipelines for antimicrobials.

Enormous advances and changes in livestock production systems, including infection control via biosecurity and vaccines, have enabled the reduction of AMU in livestock. However, current societal challenges, such as the rising cost of food and lack of access to paid sick days, continue to drive up AMU and AMR in some countries. Incorporating all these drivers into an integrated surveillance system would be impossible. But interpreting the results generated by integrated surveillance systems in context is critical to ensure that appropriate recommendations and actions are taken in an individual country. This contextualisation of surveillance data is best achieved through engagement of multi-disciplinary teams. Many integrated surveillance systems do this already; for example, CIPARS and DANMAP host annual stakeholder meetings where key results are presented and feedback is sought [2,39]. This is an important first step in the knowledge-to-action cycle. More ongoing consultation and engagement are needed to facilitate not just better data contextualisation but also correction of actions if outcomes are different than expected. In a time when surveillance budgets are already being cut in many countries, additional resources and time to enable more and better integration and participation are hard to access.

Finally, regular and cyclical evaluation of integrated surveillance systems are essential to gather data on the effects and areas requiring improvement. Evaluations are required both for the technical aspects of sectoral surveillance (e.g. sensitivity, timeliness, costs, benefits) and for elements specific to integration (e.g. comparability of data, quality of collaboration, equitable distribution of resources between sectors, added value). Guidance has been developed by the CoEvalAMR consortium on how to select a suitable framework or tool for evaluating integrated surveillance systems for AMR and AMU [40], and tools have been applied and evaluated in different contexts [41,42].

Conclusion

Integration is resource-consuming and requires surveillance actors to step out of their comfort zone by adapting to the expectations and needs of others [43]. Current evidence shows that the value of integrated surveillance is highly context specific. There is no one-size-fits-all model; the utility of integrated surveillance depends on national priorities, the maturity of existing systems and the ability to translate information into actionable policies. Countries with years of longitudinal data may extract different insights than those just beginning their surveillance journeys. The challenge is to find the right degree of structural and information integration. For integration to be effective and sustainable, it must be anchored in local realities and developed with a clear understanding of needs, capacities, resources and investment. There is no consensus on a step-by-step process to follow to establish and implement an integrated surveillance system at the national level. Still, it is often observed that surveillance systems expand gradually from local to national level, and from sector-specific initiatives to an integrated surveillance system.

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Conflict of interest

Lis Alban works for an organisation that gives advice to farmers and the meat processing industry.

Surveillance intégrée de la résistance aux antimicrobiens : enjeux et orientations

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Résumé

Dans le cadre « Une seule santé », la surveillance intégrée de l'utilisation des agents antimicrobiens et de la résistance à ces agents est une surveillance exercée dans une perspective à la fois systémique, intersectorielle et multipartite, qui éclaire et guide les décisions sur les actions à mener pour réduire la résistance aux antimicrobiens afin que l'efficacité des agents antimicrobiens soit préservée pour les générations futures. Si ce modèle bénéficie d'un large soutien, sa mise en œuvre reste principalement circonscrite aux pays à revenu élevé. Les auteurs dressent un état des connaissances sur la surveillance intégrée de l'utilisation des agents antimicrobiens et de la résistance à ces agents aux niveaux mondial, régional et national ; la valeur ajoutée de cette approche est expliquée et illustrée par des exemples concrets ; sont également examinés les lacunes et défis actuels, ainsi que les orientations pour l'avenir.

Mots-clés

Antibiotiques – Intégration – Intersectoriel – Résistance – Suivi – Systèmes de surveillance – Une seule santé.

Vigilancia integrada de la resistencia a los antimicrobianos: retos y orientaciones

C. Aenishaenslin, E.J. Parmley, S. Rüegg, B. Häsler, M. Bordier, M.M. Sow & L. Alban

Resumen

La vigilancia integrada del uso de antimicrobianos y la resistencia a los antimicrobianos en el contexto del enfoque «Una sola salud» se basa en perspectivas sistémicas, intersectoriales y de múltiples partes interesadas que orienten las decisiones sobre las medidas para reducir la resistencia a los antimicrobianos con el objetivo de mantener la eficacia de los agentes antimicrobianos para las generaciones futuras. A pesar de que se promueve ampliamente, este tipo de vigilancia se aplica principalmente en países de ingresos altos. Este artículo ofrece una visión general del estado de los conocimientos sobre la vigilancia integrada del uso de antimicrobianos y la resistencia a los antimicrobianos a nivel mundial, regional y nacional; presenta su propuesta de valor; proporciona ejemplos específicos, y analiza las brechas, los retos y las orientaciones futuras.

Palabras clave

Antibióticos – Integración – Intersectorial – Resistencia – Seguimiento – Sistemas de vigilancia – Una sola salud.

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Table I

National integrated surveillance systems for antimicrobial resistance

Surveillance system	Country
BELMAP	Belgium
ONERBA	France
Japan surveillance system	Japan
NethMap/MARAN	The Netherlands
ANRESIS/ARCH-Vet	Switzerland
UK surveillance system	United Kingdom
DANMAP	Denmark
NORM/NORM-VET	Norway
NARMS	United States of America
CIPARS	Canada
SONAAR	Scotland
FINRES-Vet	Finland
ZoMo	Germany

ANRESIS: Swiss Centre for Antibiotic Resistance
BELMAP: assembles all publicly available national data (Belgium) on antimicrobial usage and resistance in humans, livestock, food and the environment
CIPARS: Canadian Integrated Program for Antimicrobial Resistance Surveillance
DANMAP: Danish Integrated Antimicrobial Resistance Monitoring and Research Programme
FINRES-Vet: Finnish Veterinary Antimicrobial Resistance Monitoring and Consumption of Antimicrobial Agents
MARAN: Monitoring of Antimicrobial Resistance and Antibiotic Usage in Animals in the Netherlands
NARMS: National Antimicrobial Resistance Monitoring System (USA)
NethMap: Consumption of Antimicrobial Agents and Antimicrobial Resistance among Medically Important Bacteria in the Netherlands
NORM: Norwegian Surveillance System for Antimicrobial Resistance in Microbes
ONERBA: Observatoire National de l'Épidémiologie de la Résistance Bactérienne aux Antibiotiques (France)
SONAAR: Scottish One Health Antimicrobial Use and Antimicrobial Resistance
ZoMo: Zoonosis-Monitoring programme (Germany)

Source: adapted from Delpy *et al*. [10].

Note: there may be other, albeit little-developed integrated systems apart from the ones listed, e.g. in countries participating in the World Health Organization's Global Antimicrobial Resistance and Use Surveillance System.

Table II

Examples of major global and regional surveillance systems for antimicrobial resistance and use, and information on their cross-sectoral integration

Surveillance system	Lead	Coverage; focal area	Key features	Cross-sectoral integration
WHO Tricycle	World Health Organization (WHO)	LMICs (primarily); One Health	Targets extended-spectrum beta-lactamase producing *Escherichia coli* using AMR data from humans, animals and the environment in a harmonised protocol	Explicitly designed to integrate AMR surveillance across human, animal and environmental sectors
Global Antimicrobial Resistance and Use Surveillance System (GLASS)[1]	WHO	Global; human health with a One Health module	Standardised global data on AMR and AMU; focus on priority bacteria that cause common and severe infections in humans. Combines routine and focused surveillance surveys and studies	One Health module for extended-spectrum beta-lactamase *E. coli* as a common indicator to be detected across human samples, poultry and water bodies
European Antimicrobial Resistance Surveillance Network (EARS-Net)	European Centre for Disease Prevention and Control	Europe (EU/EEA countries); human health	Monitors resistance in invasive bacterial infections retrieved from blood or cerebrospinal fluid samples	EU integrated reports (e.g. the Joint Inter-agency Antimicrobial Consumption and Resistance Analysis [JIACRA] reports) that combine EARS-Net data with data from food, animals and antimicrobial sales
Central Asian and European Surveillance of Antimicrobial Resistance (CAESAR)	Multipartner[2]	Countries and areas in the WHO European Region that are not part of EARS-NET; human health	Monitors resistance in invasive bacterial infections retrieved from blood or cerebrospinal fluid samples	No direct integration but connected to EARS-Net for regional aggregation

Surveillance system	Lead	Coverage; focal area	Key features	Cross-sectoral integration
Global database on ANImal antiMicrobial USE (ANIMUSE)[1]	World Organisation for Animal Health	Global; animal health	Reports AMU and AMR in animals; veterinary drug use surveillance	No direct integration, but Tripartite project ongoing to enhance interoperability[1]
The International FAO Antimicrobial Resistance Monitoring System (InFarm)[1, 3]	Food and Agriculture Organization of the United Nations (FAO)	Global; animal health and food	IT platform for countries for AMR data at isolate or aggregated level. Focus on priority bacterial species of public and animal health significance	Integrates AMR data on animals and food
ResistanceMap	One Health Trust	Global; human health and animal health	Interactive visualisation of AMR and AMU (data on the volume of antibiotic sales and consumption) from commercial, WHO and national sources	Uses data from various sources including EARS-Net, GLASS, CAESAR and several national surveillance systems
Antimicrobial Testing Leadership and Surveillance (ATLAS)	Pfizer	Global; human health and animal health	Tracks susceptibility trends across clinical isolates data through a publicly available, interactive website (atlas-surveillance.com) and a mobile application	Integrated data from a network of local laboratories worldwide and Wellcome Trust's AMR Register, an open-access platform

AMR: antimicrobial resistance
AMU: antimicrobial use
EU/EEA: European Union/European Economic Area
LMICs: low- and middle-income countries

1. FAO, WHO, the World Organisation for Animal Health and the United Nations Environment Programme are developing the Quadripartite Global Integrated System for Surveillance on Antimicrobial Resistance and Use with a shared IT platform that shares data from InFARM, ANIMUSE and GLASS and may incorporate data from other surveillance systems in the future.
2. WHO Europe, European Society of Clinical Microbiology and Infectious Diseases, Dutch National Institute for Public Health and the Environment.
3. The FAO initiative Reduce the Need for Antimicrobials on Farms for Sustainable Agrifood Systems Transformation (https://www.fao.org/antimicrobial-resistance/background/fao-role/renofarm/en) aims to enhance the data contribution of countries to InFarm by supporting capacities among those who collect data.

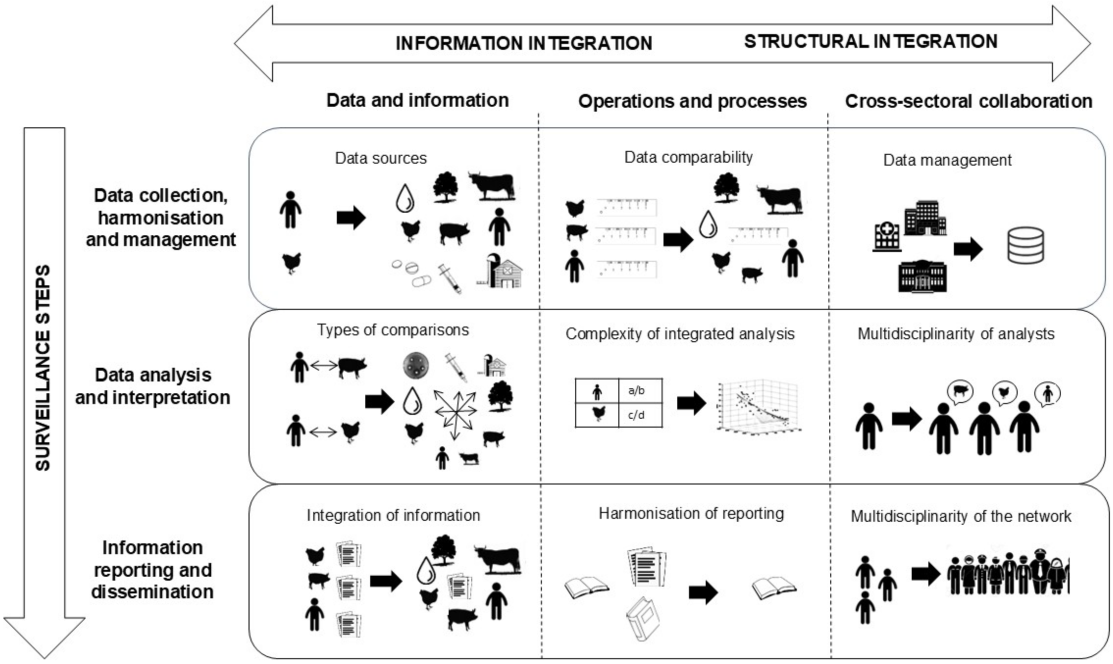

Figure 1

Integration in One Health surveillance for antimicrobial resistance

This figure illustrates the different types of integration that can occur in an integrated surveillance system for antimicrobial resistance. Integration is conceptualised across the data and information integrated, the operations and processes supporting integration, and the level of cross-sectoral collaboration, and covers both information and structural integration. Each surveillance activity – data collection, analysis, interpretation and dissemination – can achieve varying degrees of integration.

Adapted from Aenishaenslin *et al.* [12].

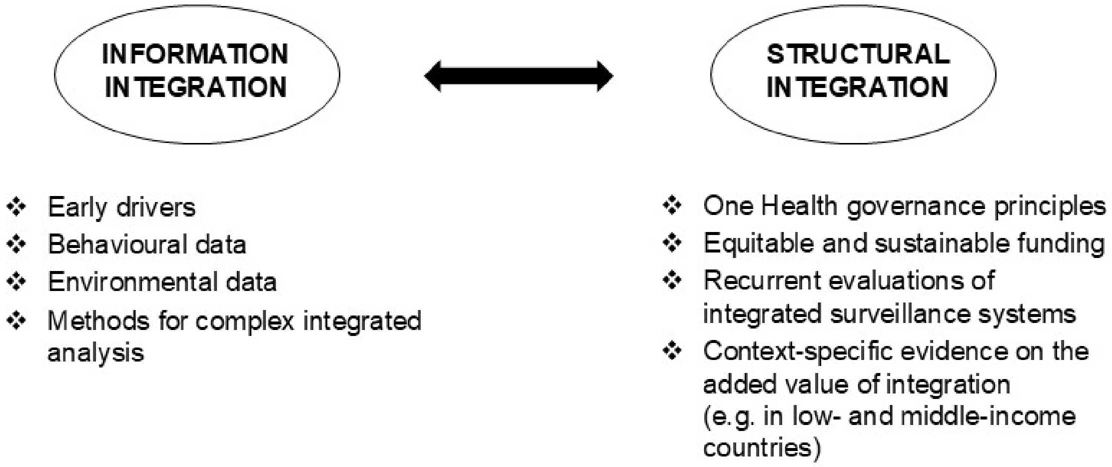

Figure 2

Key gaps and challenges in implementing integrated surveillance systems for antimicrobial resistance

This figure summarises the main gaps and challenges that remain to be addressed to accelerate the implementation of integrated surveillance systems for antimicrobial resistance at the global, regional and national levels. These gaps relate both to the type of information that is integrated (What is under surveillance?) and to the structural aspects of integration (How is surveillance conducted?)