Research Directions: One Health

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One Health governance principles for AMR surveillance: a scoping review and conceptual framework

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Abstract

Antimicrobial resistance (AMR) is a pressing global health issue with serious implications for health, food security, and livelihoods. Collective action, from local to global, that draws on the One Health (OH) approach to facilitate collaboration between the human, animal, and environmental sectors is required to inform initiatives to mitigate AMR. For AMR surveillance, this involves applying an intersectoral, multistakeholder perspective to guide the co-creation of knowledge and policy around the collection, analysis, and application of surveillance data to detect, monitor, and prevent AMR health threats. Currently, there is little available evidence on how to operationalize a OH approach to support integrated AMR surveillance systems, or on how the governance of such systems facilitates intersectoral action on AMR. We conducted a scoping review of the literature to identify the governance domains most relevant to applying the OH approach to the design and evaluation of AMR surveillance systems. We found that governance is a crucial component of the development of surveillance systems equipped to tackle complex, structural issues such as AMR. The governance domains identified include participation, coordination and collaboration, management, sustainability, accountability and transparency, and equity. These domains are relevant throughout all stages of policy design, implementation, and evaluation of AMR surveillance systems. Equity is both a domain and an essential component of the other domains. All the domains are interdependent and co-constitutive, so that progress in one domain can accelerate progress in another. The conceptual framework presented in this article can inform the design and evaluation of OH AMR governance systems and other complex health challenges that have similar barriers and facilitators to OH governance. The qualitative evaluation questions developed for each domain facilitate assessment of the breadth (the range of actors involved in governance) and depth (how meaningful their engagement is) for each domain relevant to OH governance. Finally, the prioritization of formal, sustainable, and democratic governance of AMR can help to facilitate achievement of the sustainable development goals (SDGs) and promote conservation of the use of antimicrobials for future generations.

Impact Paper

Cite this article: Ruckert A, Harris F, Aenishaenslin C, Aguiar R, Boudreau-LeBlanc A, Pedro Carmo L, Labonté R, Lambraki I, Parmley EJ, and Wiktorowicz ME (2024). One Health governance principles for AMR surveillance: a scoping review and conceptual framework. *Research Directions: One Health*. **2**, e4, 1–14. https://doi.org/10.1017/one.2023.13

Received: 4 April 2023
Revised: 16 November 2023
Accepted: 24 November 2023

Keywords:
Antimicrobial resistance; One Health; surveillance; governance; evaluation

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Introduction

Antimicrobial resistance (AMR) is a complex and multifaceted global public health issue that can only be addressed through collective action across all levels, from local to global. AMR can be accelerated by antimicrobial use (AMU) in humans, animals, and the environment, and by anthropogenic activities affecting microbial organisms found in marine, freshwater and terrestrial ecosystems, wastewater treatment plants, agricultural sites, aquaculture operations, and hospitals. AMR has the potential to cause severe negative consequences for global health, food security, and livelihoods (Holmes et al., 2016). However, AMR is not a new threat. Drug-resistant bacterial infections already cause an estimated 1.27 million deaths per year, mainly in low-resource settings, a figure expected to rise to an estimated 10 million per year by 2050 (O'Neill, 2016; Murray et al., 2022). An additional 5.7 million people die annually from a lack of access to antibiotics due to inequitable distribution of resources that jeopardizes the world's ability to achieve the Sustainable Development Goals (SDGs) (Jasovský et al., 2016). The resulting burden on healthcare, disease treatment, and infection prevention could shrink the annual global Gross Domestic Product by 3.8% by 2050 (World Health Organization [WHO], 2019). To address this growing health burden, effective surveillance systems guided by a One

Health (OH) approach are imperative to inform stewardship strategies focused on the judicious (or appropriate) use of antimicrobials.

One Health can be defined as "an integrated unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems" (One Health High-Level Expert Panel et al., 2022). For an initiative to abide by OH principles, it must involve the co-creation of knowledge and policy coordination across relevant sectors, rather than multi-disciplinary work within silos (dos S. Ribeiro et al., 2019). Recent research defines integrated OH surveillance of AMU and AMR as "surveillance that is based on a systemic, cross-sectoral, multi-stakeholder perspective to inform mitigation decisions with the aim to keep antimicrobials effective for future generations" (CoEvalAMR, 2022). OH surveillance of AMR and AMU involves the collection and analysis of data to detect, monitor, and prevent AMR health threats, and facilitates the development of initiatives to mitigate AMR (Johnson, 2015). While many protocols exist for the evaluation of AMR surveillance, limited evidence exists on how to effectively operationalize a OH approach to support the integration of surveillance systems for AMU and AMR (Aenishaenslin et al., 2021), and even less on how OH surveillance systems are best governed.

Governance is defined as the processes through which governmental and non-governmental actors within civil society and the private sector exercise power and authority and utilize resources to influence, develop, manage, and implement policies at local, national, and global scales (Biswas, 2020). The governance of surveillance systems for AMR consists of a set of strategies, rules, norms, principles, and procedures that frame the operation and implementation of surveillance to inform decisions. In the case of OH surveillance systems, these elements (strategies, rules, norms, principles, and procedures) should be made accessible to all sectors and parties involved and surveillance actions coordinated across sectors.

To facilitate effective surveillance, OH governance systems must include the political sphere to reconcile competing perspectives and interests by overseeing the coordination of legislation, policies and programs, knowledge, and resources across the human, animal, and environmental health sectors (Food and Agriculture Organization of the United Nations [FAO] et al., 2019). A governance system applying the OH approach in the surveillance of AMU and AMR must also encapsulate trans-disciplinary and cross-sectoral efforts, integrating global and local-scale understandings from science to cross-sectoral partnerships set at multiple levels (Max-Neef, 2005).

In this paper we build upon an earlier conceptual framework for the evaluation of AMR surveillance systems (Aenishaenslin et al., 2021), expanding it to account for OH governance of such systems. We do so by identifying the governance domains and principles most relevant and applicable for a OH approach to AMR surveillance systems. A conceptual framework and string logic model that delineates how the domains impact and reinforce each other is then developed. As AMR is exacerbated by structural political-economic issues and interrelated dynamics in human, animal, and environmental health sectors, intersectoral coordination at governance and operational levels is imperative. Implementation facilitators and barriers that interact through complicated pathways are considered.

Materials and methods

Arksey and O'Malley's (2005) methodological framework was used to conduct a scoping review that identifies and maps the governance domains relevant to a OH approach in the context of surveillance systems for AMR. Scoping reviews facilitate the investigation of broad research questions that require a systematic mapping of the volume and focus of available scientific literature on a particular topic (Munn et al., 2018). These reviews are useful for developing specific research questions that may be addressed using more in-depth review methodologies and for uncovering and highlighting existing knowledge gaps within the literature. The three guiding research questions of the scoping review were:

1. What governance domains relevant for AMR surveillance are identified in the academic literature?
2. Why are the governance domains important and how do they impact OH principles for surveillance systems?
3. How can governance frameworks for AMR surveillance guided by a OH lens be operationalized and implemented and what are the barriers and facilitators?

PubMed, Web of Science, and Public Health (ProQuest) databases were searched to identify relevant literature, with inclusion and exclusion listed in Appendix A. As scoping methods are intended to be iterative, inclusion and exclusion criteria were developed prior to conducting the search while remaining flexible to facilitate a comprehensive engagement with the literature (Arksey and O'Malley, 2005). The search strategy, developed in consultation with a Global Health librarian, can be found in Appendix B. The search returned 120 results, 29 of which were removed as duplicates. Two researchers independently screened the titles and abstracts of the 91 remaining articles and resolved any disagreements through discussion with a third researcher in weekly meetings and via email. During the second round of screening, two researchers independently assessed the full text of the 29 remaining articles against the inclusion and exclusion criteria. The remaining 24 articles were collated with three articles identified during a previous study and 18 additional sources generated via citation searching, bringing the total number of articles to 40. A visual summary of the selection process can be found in the PRISMA diagram in Appendix C. The protocol, reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) 2015 statement guidelines, can be found in Appendix D (Moher et al., 2015). A summary of the articles used is presented in Appendix E.

A thematic analysis of the retrieved data was conducted by one researcher using NVivo 12 software. Coding categories were deductively derived and adapted from Anderson et al.'s (2019) governance framework for assessing national action plans for AMR. Two additional researchers reviewed the coded information; any disagreements about the coded material were resolved through weekly discussion. Our coding nodes include the following governance domains: participation; collaboration/coordination; management; sustainability; accountability/transparency; and equity. As the governance body of the surveillance system for AMU and AMR usually operates at the state level, information pertaining to national governance was prioritized over the global level. The data was coded into descriptive subcategories within each

https://doi.org/10.1017/one.2023.13 Published online by Cambridge University Press

domain that outlined the nature of the governance dimension (definition); why it is relevant in the context of surveillance systems for AMU and AMR (its impact); and how it could be facilitated, along with barriers to its implementation (see NVivo 12 node structure in Appendix F).

Results

We first discuss participation as an enabling factor within the process of policy design and development, before highlighting the role of governance principles in applying a OH approach in policy operationalization and implementation (coordination/collaboration; management; sustainability; accountability/transparency) and finally, the cross-cutting theme of equity. Each section includes a definition of the relevant governance domain, before reflecting on how surveillance systems can be enhanced by implementing the OH governance principle.

Participation

Engagement of relevant actors, including public and private sector representatives as well as technical experts, is an important aspect of any governance system and a crucial ingredient of the OH approach. The commitment of stakeholders through the involvement of their representatives in a collective decision-making process can lead to the inclusion of important sectoral considerations that enhance policy outcomes. Participant adherence to proposed policy frameworks is fostered, thereby creating the conditions for policy success (Bordier et al., 2021). Participation is the "active involvement of a group of individuals in a collective process on actual or intended actions of administrative authorities" (Addink, 2019). To embody the OH ethos in their governance, surveillance systems for AMR should involve participation from stakeholders across the human and animal health, agriculture, fisheries, and environmental sectors that impact and are impacted by AMR so that surveillance priorities are determined collectively (Bordier et al., 2018; Joshi et al., 2018; Rüegg et al., 2018; Anderson et al., 2019; Ahmed et al., 2022). Stakeholders include members of the public and private sectors, such as government ministries, professional, statutory, and regulatory bodies, the pharmaceutical, food, and agricultural industries, academia, laboratories, donors, development partners, research networks, media, and civil society organizations, such as community groups and patient organizations (Joshi et al., 2018; Anderson et al., 2019; Ahmed et al., 2022).

Broad participation increases support for activities and the evaluation of surveillance systems, informs strategic direction, and aids in the identification of potential implementation issues (Tangcharoensathien et al., 2017; Chua et al., 2021). High rates of participation and community engagement diversify the perspectives involved and enhance the legitimacy and sustainability of surveillance systems and policies (Birgand et al., 2018; Anderson et al., 2019; Chua et al., 2021). Holding consensus-building consultations – if well-designed – facilitates a redistribution of knowledge and power that increases credibility and decreases politicization of initiatives (Birgand et al., 2018). Early and extensive engagement that includes stakeholder perspectives can build consensus on values and vision during the conceptualization stages of the surveillance system (Boudreau LeBlanc et al., 2022). The limitations and needs of stakeholders and end-users ideally influence the structure and processes of surveillance systems, for example, through the participatory development of indicators relevant to stakeholders' aims and through the harmonization of intersectoral efforts and priorities (Wielinga et al., 2014; Bordier et al., 2018; Rüegg et al., 2018). The engagement of subject matter experts and/or technical advisory committees supports the development of evidence-informed policies and lends credibility to initiatives (Anderson et al., 2019). Involving local stakeholders in the analysis of surveillance data facilitates stronger feedback mechanisms that are more aligned with users' needs (Anderson et al., 2019). Finally, participant feedback can aid in the development of effective evaluation tools to assess the effectiveness, sustainability, and equity of integrated surveillance systems (Haworth-Brockman et al., 2021).

Shared leadership and participatory governance mechanisms facilitate active and ongoing stakeholder involvement in the planning, implementation, operation, and evaluation of OH surveillance systems (Rüegg et al., 2018; Chua et al., 2021). Engagement of independent agencies in evidence synthesis may aid in discerning which sectors, scales, and disciplines to include in the governance and implementation of new surveillance systems and the development of complementary participatory mechanisms (Birgand et al., 2018; Bordier et al., 2018). Governments, policymakers, and practitioners should take the initiative to expand the relevant sectors and disciplines as AMR is assessed, monitoring becomes more refined, and the knowledge more precise (Ahmed et al., 2022; dos S. Ribeiro et al., 2019). Inclusion of the environment sector, which is often absent from AMR-related activities yet represents an important transmission pathway, must be ensured (Baum et al., 2017; Bennani et al., 2021; Chua et al., 2021; Ahmed et al., 2022; dos S. Ribeiro et al., 2019; Johnson et al., 2018). Other underrepresented fields vary by surveillance system but include human health, social science, economics, anthropology, veterinary medicine, and experts from the wildlife sector (dos S. Ribeiro et al., 2019; Hein et al., 2022). Engagement of community actors is difficult but can be facilitated through culturally appropriate communications and clear messaging in the local language that includes the benefits of participation (Donado-Godoy et al., 2015; dos S. Ribeiro et al., 2019; Harant, 2022). Finally, non-binding and binding but unenforceable national and international treaties may also increase participation but not necessarily compliance (Phelan and Gostin, 2017).

Collaboration and coordination

Collaboration and coordination are crucial elements in any governance system that aims to achieve policy goals through the engagement of a multiplicity of actors across a variety of sectors. A collaborative governance structure is important for building trust, credibility, and a sense of ownership over initiatives among a diverse set of stakeholders (Sommanustweechai et al., 2018; Boudreau LeBlanc et al., 2022). While collaboration and coordination differ, the two concepts were often conflated in the reviewed literature and are therefore addressed in the same section. Coordination is the arrangement of team members' actions so that the correct type of action(s) is performed at the right time(s) and location(s) to increase efficiency and synergy during policy implementation (Eccles, 2016). From the 'global commons' perspective of Elinor Ostrom (2000) and Bruno Latour (2007), coordination can be scaled up at the sectoral level as a collective set of actions and to manage the evolution of social norms. These actions must be coordinated vertically within governance bodies that structure knowledge exchanges from local to global and horizontally across sectors and disciplines (Anderson et al., 2019).

https://doi.org/10.1017/one.2023.13 Published online by Cambridge University Press

In the context of surveillance systems, coordination is also influenced by international guidance, context, constraints, and expectations of local actors (Bordier et al., 2018).

To embody the OH approach, collaboration should involve active participation from a diverse group of actors during all stages of the surveillance program working toward a common goal (Birgand et al., 2018; Bordier et al., 2018; Sommanustweechai et al., 2018; Anderson et al., 2019; Sumpradit et al., 2021; Ahmed et al., 2022). Actors involved would engage through roles and responsibilities, technical mechanisms, and allocation of resources that facilitate the coordination of collaboration, and thus represents conjoint operation (Bordier et al., 2018). Engagement can include activities within a specific discipline in service of cross-sectoral aims, or cross-sectoral collaborative efforts to meet metrics set by one sector (Baum et al., 2017). Such cooperation allows for the development of 'boundary-spanning approaches', whether conceptual, such as 'ecosystem services' or practical, such as policies, norms, and standards, facilitating the translation of goals, challenges, and issues across sectors (Limmathurotsakul et al., 2019).

Collaboration and coordination across the various levels of governance is necessary for the planning, management, implementation, and evaluation of effective AMR-related activities (Sumpradit et al., 2021; Ahmed et al., 2022; Boudreau LeBlanc et al., 2022). International and regional collaboration increases the expertise and quality of national surveillance systems, especially in low and middle-income countries (LMICs), facilitating knowledge sharing and reducing overlap and duplication of efforts (Chua et al., 2021; dos S. Ribeiro et al., 2019; Uchtmann et al., 2015; Wernli et al., 2020). Integrating surveillance systems increases the sustainability and cost-effectiveness of initiatives by allowing participants to build social capital and share resources, facilities, and skills (Uchtmann et al., 2015; Queenan et al., 2016). In addition, collaboration can lead to the co-construction of norms and values that guide strategies and actions (Boudreau LeBlanc et al., 2022). A shared vision can overcome competing interests to create a culture of change, strengthen leadership, and increase participants' ability to advocate for regulatory or policy reform (Joshi et al., 2018; Boudreau LeBlanc et al., 2022). As Ostrom (2000) emphasizes, the management of shared goods (e.g., monitoring data) and collective issues (e.g., AMR) requires the coordination of collaborative efforts, built on a consensual premise. An absence of consensus and trust may lead to a tragedy of the commons, as individual management of public goods, matched with shared consequences, can hasten depletion of common pool resources which is ultimately detrimental to all. In the challenge of identifying a consensus within a multi-stakeholder system of diverse interests, Michael Heller (2013) proposes a focus on losses and waste – since resources (here technologies, as the data of surveillance and antibiotics in medicine) are shared, such understanding can build the impetus for responsible resource management (e.g., ensuring data protection and judicious use of antibiotics) as a first step towards consensus. Through its Global Action Plan (GAP) on AMR in 2015 and the creation of the Global Antimicrobial Resistance and Use Surveillance System (GLASS), the WHO offers guidance on the creation of national action plans (NAPs) on AMR and coordinates international surveillance (Kaiser et al., 2022). This work was followed by the creation of an AMR Quadripartite. Global health governance actors thus play a significant role in steering action against AMU and AMR.

Incorporating mechanisms to facilitate intersectoral and interdisciplinary coordination and collaboration at every level of governance and in each stage can help to overcome the fragmentation and siloing that has marked previous attempts to build surveillance systems in many countries (Bordier et al., 2018; Tangcharoensathien et al., 2017; Johnson et al., 2018). Cross-sectoral collaboration can foster a multidisciplinary approach that promotes a more in-depth understanding of each sector's stakeholders and their knowledge, interests, constraints, and obligations, leading to better outcomes for human, animal, and environmental health (Uchtmann et al., 2015; Queenan et al., 2016; Bordier et al., 2018). Intersectoral coordination promotes active stakeholder participation, emergence of leaders valued by their peers, and increases the effectiveness of coalitions during implementation (Joshi et al., 2018; Ahmed et al., 2022).

Collaboration and coordination within AMR surveillance systems contribute to human and animal health through the development of more effective epidemiological tools and efficient diagnoses of human and animal diseases and reduce the risk of environmental contingencies that may arise from the (theoretically) predictable ecological cascades of antibiotic use (Uchtmann et al., 2015). Involving the private sector will also increase access to data, sampling sites, and laboratory capacity for surveillance (Donado-Godoy et al., 2015; Mader et al., 2022). Greater research and disease mapping increases trust between stakeholders, which leads to greater data sharing. Enhanced communication can reduce redundant data collection and related costs and promotes better data management, analysis, and reporting practices (Uchtmann et al., 2015; Rüegg et al., 2018). In addition, collaboration facilitates more cohesive, multidisciplinary data analyses and promotes rapid communication and contingency planning between human and animal health sectors if new AMR risks are detected (Rüegg et al., 2018; Bennani et al., 2021).

To understand what level and form collaboration must take to progressively realize the OH approach while remaining cost-effective (Bordier et al., 2018), recognition of all the systems and linkages involved is necessary for effective coordination (Bennani et al., 2021). This entails organization and planning at the policy, institutional, and operational levels and the inclusion of experts in OH (Bordier et al., 2018; Boudreau LeBlanc et al., 2022; Tangcharoensathien et al., 2017; Johnson et al., 2018). Democratizing governance by reframing solutions in terms of their shared value while maintaining the functionality of systems can increase the influence of civil society, non-governmental organizations (NGOs), public-private collaborations, and other key non-governmental stakeholders (Birgand et al., 2018). Sustaining collaborative governance can be facilitated by technical and steering committees that bring members of different sectors, disciplines, government ministries, professional and civil society organizations, and academia together with subcommittees and working groups for specific activities as needed (Bordier et al., 2018; Sommanustweechai et al., 2018; Anderson et al., 2019; Sumpradit et al., 2021; Ahmed et al., 2022). Stakeholder commitment to the collaborative process can be fostered through the creation of strong communication and consultation channels within surveillance systems. The need for shared language (terminologies, ontologies, and even philosophies) is particularly salient throughout the planning and implementation processes, contributing to development of transdisciplinary and trans-sectoral ethics that facilitate ongoing communication and data sharing (Bordier et al., 2018; dos S. Ribeiro et al., 2019; Wielinga et al., 2014; Uchtmann et al., 2015). Clarity on the mandates and obligations of each committee, sector, discipline, and public-private partnership involved in surveillance can help to

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address questions of jurisdiction and responsibility (Baum et al., 2017; Bordier et al., 2018; dos S. Ribeiro et al., 2019; Joshi et al., 2018).

Management

The management domain involves steering, coordinating, and ensuring technical and scientific support, comprising the institutional processes, agencies, and resources used to govern a surveillance system for AMR. Strategic planning focuses efforts to drive action on goals with *Specific, Measurable, Achievable, Relevant, and Time-bound* (SMART) objectives and quantitative targets, supported by situational analyses (Anderson et al., 2019). Management also involves building OH surveillance capacity early enough to foster strategic and ethical leadership that guides coordination and learning between stakeholders and policymakers (Boudreau LeBlanc et al., 2022; dos S. Ribeiro et al., 2019; Sumpradit et al., 2021; Hein et al., 2022). Management further includes monitoring the synergistic effects and impacts of integrated surveillance systems over time, including adherence to surveillance commitments and protocols (Bordier et al., 2018).

Leadership can dismantle silos and advance multisectoral implementation plans to operationalize the OH approach in surveillance systems (Johnson et al., 2018). Effective management practices strengthen implementation, build monitoring capacity, and facilitate adherence to guidelines (Mölstad et al., 2017; Tangcharoensathien et al., 2017; Joshi et al., 2018; Sommanustweechai et al., 2018; Ahmed et al., 2022). Management also ensures the availability and administration of human and economic resources and addresses systemic or institutionalized issues, enabling sustainable collaboration (Ahmed et al., 2022; dos S. Ribeiro et al., 2019; Hein et al., 2022). Committed leadership is necessary for nonhierarchical, trusting relationships built on flexibility, reflexivity, recursiveness, and democratic decision-making (Rüegg et al., 2018). Situational analyses support management by enabling an understanding of factors driving AMR in a particular context to inform surveillance of AMU aims and actions, identify best medical and administrative practices, and align regional, national, and international efforts to address the collective issue (Essack et al., 2017; Sommanustweechai et al., 2018; Anderson et al., 2019; Iskandar et al., 2021).

Clear quantitative goals for AMU and AMR surveillance systems can promote accountability and motivate stakeholders to work towards a common objective (Anderson et al., 2019; Chua et al., 2021; Sumpradit et al., 2021). Setting and adhering to SMART targets and indicators and embedding monitoring and evaluation activities within surveillance systems can inform future AMR policies and increase resource mobilization (Anderson et al., 2019; Chua et al., 2021; Johnson et al., 2018; Joshi et al., 2018). A OH database sensitive to the effects of governance and other situational factors could increase understanding of the range of interventions feasible in a particular context (Wernli et al., 2020). Surveillance metrics should capture AMU and AMR in human, animal, and environmental sectors, the quality of antimicrobial data, and laboratory and human resource capacity, and support external evaluation (Anderson et al., 2019). Greater specificity on the actions necessary to achieve objectives is needed in most National Action Plans (NAPs), and in many national surveillance systems (Munkholm and Rubin, 2020). Linking surveillance to quantitative targets should be incremental for countries with lower capacity for OH surveillance and tailored to the local context (Anderson et al., 2019; Hein et al., 2022; Mader et al., 2022), while enabling local stakeholders to develop their own specific, time-bound action plans could foster progress towards national targets (Anderson et al., 2019).

Management also entails assessing the strengths, weaknesses, and gaps of current systems using regular baseline assessment and self-report surveys (Chua et al., 2021). Routine and interim monitoring mechanisms with defined process indicators are essential to track performance and to offer the evidence needed to inform policies and resource allocation (Johnson et al., 2018; Joshi et al., 2018). Alignment of data across sectors and addressing data limitations are key steps (Bennani et al., 2021). For decentralized governance systems, policy consensus on standardization, data collection, storage, and reporting at the subnational level needs to be developed (Otto et al., 2022). Local stakeholders should assist with interpretation of data to ensure that it meets their needs and aligns with national targets and deadlines (Anderson et al., 2019). The transmission of regional and organizational level data and establishing deadlines to review the progress of specific activities is important to facilitate the creation of feedback mechanisms and measure improvements in surveillance systems over time (Anderson et al., 2019; Ahmed et al., 2022). Data sharing guidelines, agreements, standards, and reporting and information flow systems should first be developed (dos S. Ribeiro et al., 2019). The WHO's Global Antimicrobial Resistance and Use Surveillance System (GLASS) can assist with data reliability and representativeness by facilitating standardized national data collection and reporting (Iskandar et al., 2021). Feedback can be built into surveillance systems for AMU and AMR (Johnson et al., 2018); several European animal bacterial pathogen surveillance systems provide data tailored to guide AMR policymaking and to measure the impact of the NAP (Mader et al., 2022). Creating a national coordinating center to guide national strategic planning and monitor implementation and quality of surveillance systems is advised (Iskandar et al., 2021). In Thailand, a strategic coordinating group promoted horizontal policy coordination across responsible agencies (Sumpradit et al., 2021).

Making AMR a national priority is essential for improved governance, leadership, and funding (Otto et al., 2022). A formal OH governance body is important to guide the organization, momentum, and implementation of a OH surveillance system, as is moving towards a network governance approach that is less hierarchical (Birgand et al., 2018; Johnson et al., 2018; Sumpradit et al., 2021). Network governance involves the fusion of 'collaborative public goods and service provision with collective policymaking' (Isett et al., 2011) guided by trust, mutual interdependence, reciprocity, and negotiation among actors (Provan and Kenis, 2008). Network governance arises in situations where administrative or political actors need to engage with others to form alliances, attain resources, and address problems that go beyond one sector (Wang and Ran, 2021).

Development of an iterative roadmap that factors in differences in values, interests, and perceptions can facilitate strategic, ethical, and empowering leadership within multisectoral or multidisciplinary teams (Boudreau LeBlanc et al., 2022). Providing evidence of success by, for example, demonstrating the cost-effectiveness of OH surveillance systems may assist in increasing buy-in (Baum et al., 2017; Hein et al., 2022; Johnson et al., 2018; Wernli et al., 2020; Sumpradit et al., 2021), with the results made public to improve confidence in the system (Hein et al., 2022). Attention to

https://doi.org/10.1017/one.2023.13 Published online by Cambridge University Press

the SDGs and fit with the local context can also increase the likelihood of successful implementation (Wernli et al., 2020). Demonstrating success can support political will to sustain funding; some states made reimbursement for AMR stewardship activities conditional on meeting performance targets (dos S. Ribeiro et al., 2019; Mölstad et al., 2017; Kirchhelle et al., 2020; Sumpradit et al., 2021; Harant, 2022; Hein et al., 2022). As funding was highlighted as a major constraint on effective surveillance in many studies (Ahmed et al., 2022; dos S. Ribeiro et al., 2019; Harant, 2022; Hein et al., 2022; Mader et al., 2022; Wakimoto et al., 2022), improving the financial, human, and physical resources available for surveillance is essential (dos S. Ribeiro et al., 2019; Otto et al., 2022). Funding processes may need to be restructured to enable intersectoral collaboration, communication, and the expansion of surveillance (Johnson et al., 2018).

Sustainability

Political sustainability is a central component of effective governance of AMR surveillance, especially as surveillance systems can be ad-hoc, time-bound, and resource-intensive policy initiatives. It includes the structures and processes, such as funding stability, partnerships, communications, political support, and program evaluation, that facilitate the use of resources to implement and sustain evidence-based policies and programs (Schell et al., 2013). To operationalize a OH approach to surveillance systems for AMU and AMR, all sectors need adequate funding with the ability to build networks and coordinate budgets, policy reviews, and monitoring (Joshi et al., 2018).

Sustainability ensures that beneficial surveillance activities, monitoring, and evaluation can be implemented and maintained over time (Mölstad et al., 2017; Anderson et al., 2019; Ahmed et al., 2022; Harant, 2022). Economic security can facilitate more representative data collection and advanced analyses (Mader et al., 2022). Inadequate funding was cited as the greatest threat to animal health surveillance systems in Europe (Mader et al., 2022). Investing in a skilled workforce also enables the production and communication of in-depth multi-program data within a reasonable timeframe and reduces staff turnover and loss of corporate memory (Otto et al., 2022).

Several mechanisms can enhance the sustainability of AMR surveillance systems. Alignment with existing national and international health efforts, such as national health policies and the SDGs, a clear government mandate, voluntary intersectoral agreement, or national coordinating center involving a 'whole-of-government' approach may increase the legitimacy of interventions by addressing AMR (Anderson et al., 2019; Iskandar et al., 2021). Surveillance systems must be seen as able to fulfill objectives of stakeholders involved in governance and management processes (Bordier et al., 2018). Funding for collaborative activities is best embedded within each implementing agency (Sommanustweechai et al., 2018), realized at both the governance and operational levels, and should draw attention to future budget needs to enable sustainable expansion of surveillance activities (Bordier et al., 2018; Chua et al., 2021). Dedicated budgets should be transparent, explicitly outline funding sources, and cover both surveillance activities and advisory committee work (Bordier et al., 2018; Anderson et al., 2019). Intersectoral and interdisciplinary technical advisory committees can ensure that initiatives are evidence-informed and subject to monitoring and evaluation with adequate support to prevent implementation fatigue (Mölstad et al., 2017; Bordier et al., 2018; Anderson et al., 2019). Clear costing of data and an understanding of minimum levels of data collaboration needed can reduce program inefficiencies and redundancy, and increase political support, yet standards for data coordination and collaboration are often vague or absent (Baum et al., 2017; Bordier et al., 2018; Harant, 2022).

Diversifying funding to include public and private grants, endowments, and levies from domestic and international sources has proven particularly important for animal health surveillance (Uchtmann et al., 2015; Joshi et al., 2018). In resource-constrained settings, external donors, including overseas development assistance flows and nonprofit foundations, can help countries overcome financial challenges and implement their NAPs (Hein et al., 2022). Donors can also build capacity by funding training, education, and research that fosters sustainability and addresses gaps in expertise (Uchtmann et al., 2015; Iskandar et al., 2021). While dialog and partnerships with international partners and NGOs is critical for knowledge sharing and system strengthening, evidence suggests that national AMU and AMR surveillance systems require domestic funding and ongoing political engagement and support for long-term sustainability (Chua et al., 2021; Ahmed et al., 2022; dos S. Ribeiro et al., 2019; Iskandar et al., 2021; Hein et al., 2022). Intersectoral efforts to develop a strong message, collaborate with policymakers, and raise public awareness of AMR and the benefits of a OH approach can also help to generate policy support and funding (dos S. Ribeiro et al., 2019; Hein et al., 2022). The initial impetus for advocacy and AMR initiatives can be built through calls to action and kickoff meetings, sustained through fundraising and organizational commitment or via institutionalization within the government (Joshi et al., 2018). National forums that provide progress updates to stakeholders and facilitate multilevel intersectoral collaboration may encourage continued political engagement in AMR surveillance (Sumpradit et al., 2021).

Accountability and transparency

Accountability and transparency are integral to evaluation of AMR surveillance systems. Answerability is central to the concept of accountability and is defined by a relationship between parties that includes both the obligation to produce explanations for decisions or actions taken and the ability of the governing institution to levy sanctions for failure to meet standards or commitments (Anderson et al., 2019; Chua et al., 2021). Transparency, defined as open and accessible AMR policy development, implementation, and evaluation is necessary for accountability (Anderson et al., 2019). It includes making NAPs, progress reports, funding information, and accurate, up-to-date surveillance data publicly available (Anderson et al., 2019; Chua et al., 2021).

Accountability promotes a sense of ownership over decisions and activities among stakeholders (Chua et al., 2021). Answerability mechanisms that include the expectation of collaboratively-established, measurable outcomes that are straightforward foster more constructive dialog between sectors, disciplines, and stakeholders (Anderson et al., 2019; Chua et al., 2021). Sanctions that lack enforceability reduce accountability, diminishing stakeholder and public trust (Chua et al., 2021). Transparency and accountability around funding and expenditures can promote fiscal responsibility and enhance the sustainability of initiatives (Chua et al., 2021; Hein et al., 2022). Ensuring that AMR policies and surveillance data are publicly accessible in an understandable format can increase political awareness and civil society engagement (Anderson et al., 2019; Chua et al., 2021), enhancing public support for specific

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actions to address AMR (Chua et al., 2021; Harant, 2022). For LMICs, this would help to close the implementation gap (Harant, 2022).

Accountability can be facilitated in numerous ways. Participatory processes that prioritize collaboration and cooperation lead to policies that are perceived as more legitimate and sustainable than rigid, hierarchical governance structures that operate using a top-down approach (Birgand et al., 2018). Adopting a multi-stakeholder, bottom-up approach may enable greater accountability and more democratic collaboration, improving information sharing (Birgand et al., 2018). Governing bodies should therefore involve stakeholders including healthcare providers, the agricultural sector, the public, and media in the design and implementation of accountability frameworks for surveillance systems (Birgand et al., 2018; Boudreau LeBlanc et al., 2022). Creating connections between policymakers and the pharmaceutical and livestock industries may help to prevent and manage conflicts of interest at the local level that hinder fairer regulatory approaches (Khan et al., 2020; Harant, 2022). Involving relevant representatives may also increase ownership over initiatives in countries where monitoring and evaluation is technocratic and consultation often perfunctory (Hein et al., 2022).

Surveillance data should be reported annually to improve transparency, ease of monitoring and evaluation, and the quality of progress reports (Anderson et al., 2019). Information on available resources, expenditures, and funding gaps should be publicly available (Harant, 2022), along with detailed monitoring and evaluation plans and gray literature from relevant stakeholders and institutions (Hein et al., 2022). In addition, all reports should include publication dates, be made available and easily searchable on government websites, and use the same terminology as the WHO's Global Action Plan (GAP) on AMR (Harant, 2022).

Accountability for NAPs was often weak and commitments were not met within the prescribed timeframe in many countries (Harant, 2022). Providing a public explanation for failure to meet commitments can increase public trust in the government, which is necessary for increased uptake of policies and practices that limit the spread of AMR (Harant, 2022). Another way to foster accountability is by clearly defining the roles and responsibilities of implementing agencies, political bodies, and individuals (Sommanustweechai et al., 2018; Anderson et al., 2019; Ahmed et al., 2022; Harant, 2022). The nomination of one person accountable for each sector (Anderson et al., 2019) and the creation of an effective intersectoral committee to support implementing agencies would be important. Implementing agencies, in turn, should be accountable to this body (Sommanustweechai et al., 2018). In the coordination process, frameworks can provide clarity on how governing bodies are established, how often they meet, and which members are responsible for coordination and implementation activities, analysis, and provision of feedback to health professionals and agricultural trade associations, for example (Hawes et al., 2020; Harant, 2022), deepening the meaning of transparency to include the upstream governance planning. More clearly articulated accountability mechanisms are needed for NAPs and the development of surveillance systems, particularly regarding repercussions if targets are not met (Chua et al., 2021). AMR policies should set clear goals and name the agency responsible for meeting them (Chua et al., 2021), along with identifying regional and organizational feedback mechanisms and providing dates for progress evaluations of specific interventions (Anderson et al., 2019). Identifying individualized responsibilities of members of a collaboration or agency could also help reduce isomorphic mimicry and incentivize progress (Munkholm and Rubin, 2020), increasing accountability for attainable surveillance targets with tangible consequences if unmet.

Equity

Incorporating equity into a OH approach requires attention to both systemic processes and individual-level attributes that unfairly limit access to the resources and opportunities necessary for human, animal, and environmental health to be progressively and fully realized (Gislason and Stephen, 2020; WHO, 2018). Surveillance systems must consider the accessibility of healthcare services and antimicrobials and the vulnerability of certain groups to AMR exposure due to factors such as gender, socioeconomic status, and geographic location (Anderson et al., 2019; Chua et al., 2021). Historical inequities in the distribution of socioeconomic, political, technical, and environmental resources between and within high-income countries (HICs) and LMICs continue to shape access to antimicrobials and to decision-making and implementation processes, resulting in uneven AMU and AMR policies that prioritize the conservation of important antimicrobials over issues of access and mortality (Kirchhelle et al., 2020; Munkholm and Rubin, 2020; Wernli et al., 2020).

The creation of equitable AMU and AMR policies at the national and local levels involves attention to issues of access to antimicrobials and technical solutions to improve capacity for surveillance. While policies that limit over-the-counter access to antimicrobials can mitigate AMR (Chua et al., 2021; Mdegela et al., 2021; Ahmed et al., 2022), they may reduce access to life-saving drugs for populations with specific vulnerabilities in some contexts (Kirchhelle et al., 2020; Munkholm and Rubin, 2020; Chua et al., 2021). To prevent such inequitable consequences, policymakers are encouraged to adopt a broader conceptualization of equity during the development of surveillance programs and to incorporate metrics that capture wider societal impacts, including on livelihoods, poverty, and for specific marginalized groups such as women, forced migrants, and those with lower socioeconomic status (Baum et al., 2017; Chua et al., 2021). Countries that lack a safe, accessible, and affordable drug supply should consider actions to strengthen supply chain management, promote clinical guidelines, publish an essential medicine list, and regulate the post-market quality of antimicrobials (Chua et al., 2021; Mdegela et al., 2021; Hein et al., 2022). Where possible, local microbiologists and medical and veterinary professionals should be provided with training and networking opportunities to improve access to health expertise in underserved areas and capacity for data management (Uchtmann et al., 2015; Iskandar et al., 2021). Equity-conscious surveillance systems should be informed by a sex/gender-based analysis prior to implementation (Government of Canada, 2022).

At the global level, AMR increases more rapidly in LMICs than HICs (Laxminarayan et al., 2020), yet competing policy priorities, inadequate access to laboratory equipment, human and economic resources, and pay-walled academic literature has serious implications for the ability of LMICs to conduct surveillance (Uchtmann et al., 2015; Kirchhelle et al., 2020; Iskandar et al., 2021; Harant, 2022). Global AMR policy must account for the diversity of inequity across countries and regions. Diverse governance factors, such as political stability, regime type (democratic versus authoritarian states), and geographic disparities directly and

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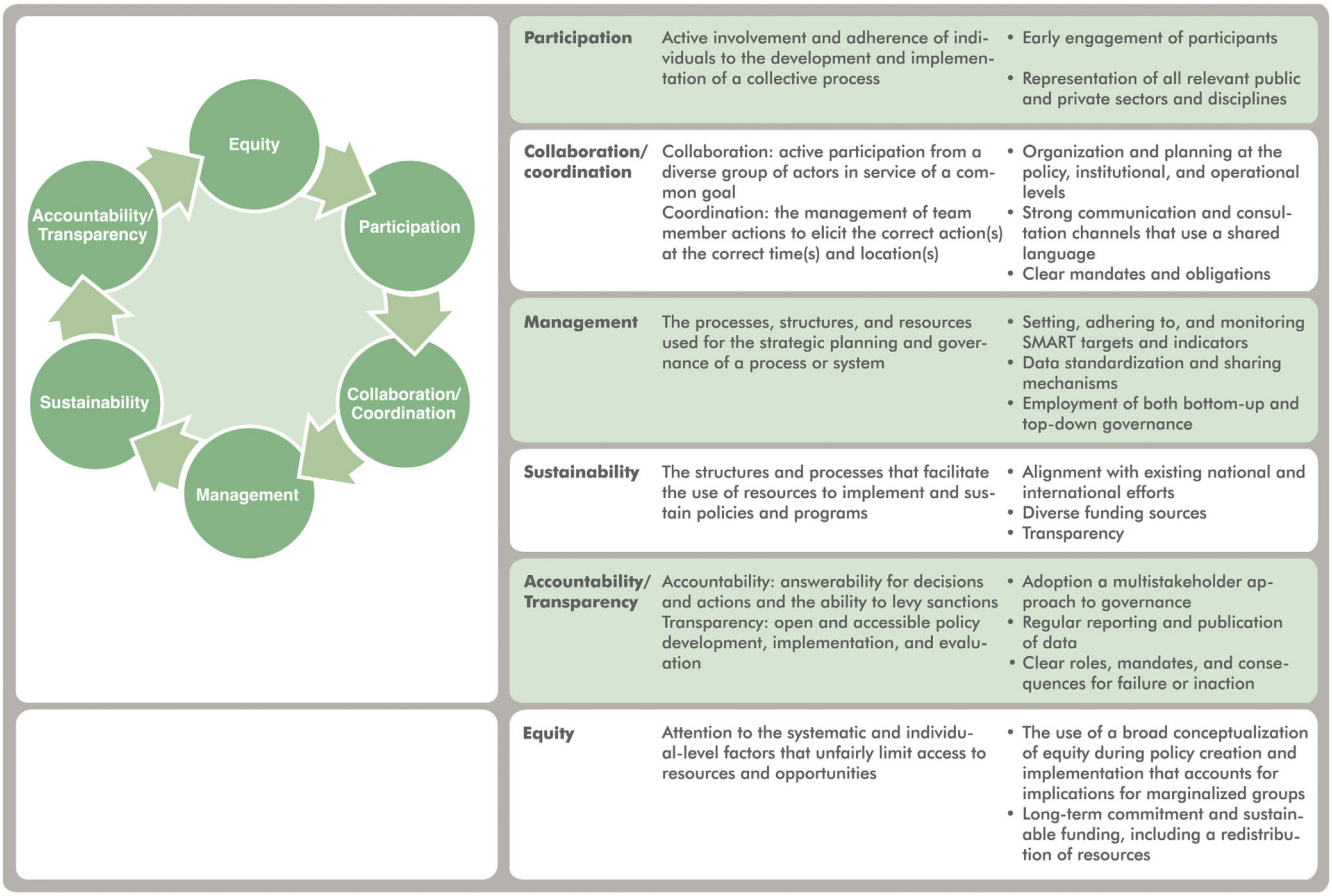

Participation	Active involvement and adherence of individuals to the development and implementation of a collective process	• Early engagement of participants • Representation of all relevant public and private sectors and disciplines
Collaboration/ coordination	Collaboration: active participation from a diverse group of actors in service of a common goal Coordination: the management of team member actions to elicit the correct action(s) at the correct time(s) and location(s)	• Organization and planning at the policy, institutional, and operational levels • Strong communication and consultation channels that use a shared language • Clear mandates and obligations
Management	The processes, structures, and resources used for the strategic planning and governance of a process or system	• Setting, adhering to, and monitoring SMART targets and indicators • Data standardization and sharing mechanisms • Employment of both bottom-up and top-down governance
Sustainability	The structures and processes that facilitate the use of resources to implement and sustain policies and programs	• Alignment with existing national and international efforts • Diverse funding sources • Transparency
Accountability/ Transparency	Accountability: answerability for decisions and actions and the ability to levy sanctions Transparency: open and accessible policy development, implementation, and evaluation	• Adoption a multistakeholder approach to governance • Regular reporting and publication of data • Clear roles, mandates, and consequences for failure or inaction
Equity	Attention to the systematic and individual-level factors that unfairly limit access to resources and opportunities	• The use of a broad conceptualization of equity during policy creation and implementation that accounts for implications for marginalized groups • Long-term commitment and sustainable funding, including a redistribution of resources

Figure 1. On the left side, there are six green circles, each containing a governance domain (participation, collaboration and coordination, management, sustainability, accountability and transparency, and equity). Each circle is connected to the next circle with an arrow to show that they form a cycle. On the right side, the domains are listed on alternating green and white backgrounds and a definition of each is provided, along with two to three examples of factors that facilitate the domain. Equity is slightly separated from the other domains to reflect that it is both a domain, and an essential component of each of the other domains.

indirectly affect their AMR landscape. This complexity extends beyond the simplistic dichotomy of HICs and LMICs, as the gap in health indicators, disease burden, and AMU can be greater between LICs and MICs than that between MICs and HICs (Kirchhelle et al., 2020; Iskandar et al., 2021). While this lack of uniformity presents challenges for global antimicrobial reform, deliberate attention to equity at the global level can help address structural inequities, particularly for marginalized groups (Anderson et al., 2019; Kirchhelle et al., 2020; Chua et al., 2021). Increasing the capacity of LMICs to generate timely, reliable, and representative data can facilitate the implementation of international surveillance policies and guidelines that meet their needs, bolster their profile on the global AMR stage, and reduce reliance on HIC data (Kirchhelle et al., 2020; Wernli et al., 2020; Iskandar et al., 2021; Harant, 2022). It may also help to prevent capability traps, in which LMIC governments are pushed to adopt unattainable AMU and AMR policy targets (Munkholm and Rubin, 2020).

Long-term commitment and sustainable funding are crucial for building infrastructure and laboratory capacity (Iskandar et al., 2021; Hein et al., 2022). This may require a transfer of resources from HICs to LMICs to expedite the development of user-friendly surveillance methods suited to resource-constrained settings, such as rapid on-site test kits and diagnostics and equipment that can handle high temperatures and humidity (Chua et al., 2021; Iskandar et al., 2021). In some countries, improvements to basic infrastructure are needed first (Iskandar et al., 2021). Academic networks can also help strengthen laboratory and clinical capabilities in LMICs (Iskandar et al., 2021). Proportional international contributions to agencies like the WHO and Fleming Fund and creation of a Global Antimicrobial Conservation Fund may facilitate noncommercial, collaborative research that advances bacteriology and OH surveillance capacity in LMICs (Uchtmann et al., 2015; Kirchhelle et al., 2020; Wernli et al., 2020; Iskandar et al., 2021). Any international organizations active in LMICs must, however, be wary of contributing to "brain drain" from local health systems (Hein et al., 2022). This may be partially mitigated by soliciting political commitment to increased health budgets in LMICs, as donor funding represents less than one percent of all health spending (WHO, 2019) and will be insufficient to address AMR on its own.

Conceptual framework for OH governance evaluation

Our findings support the development of a conceptual framework for OH governance that informs the design and evaluation of governance systems for AMR surveillance consisting of six governance domains (see Figure 1 on next page).

For each governance domain, we identify qualitative evaluation questions to assess the extent to which the OH approach has been integrated, building on our findings that connect OH principles to governance evaluation. The proposed questions (see Table 1) can support efforts to distinguish and assess the breadth

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Table 1. Domain-specific evaluation questions

Domain	Evaluation Questions
Participation	• To what extent has a high level of stakeholder participation occurred across all AMR relevant sectors during the development phase of the surveillance system? • To what extent have a technical advisory group or subject matter experts, including OH experts, engaged in developing the surveillance system? • Does an effective governance/management structure (e.g., intersectoral committee) exist that is responsible for overseeing sectoral participation? • To what extent is public representation enabled? If so, how, and if not, why not? • How was the information generated by the participatory process used by policy makers? • How is surveillance information communicated to participating stakeholders and to whom?
Collaboration/ Coordination	• To what extent is coordination between sectors and across different levels of each sector incorporated? • What is the governance/management structure (e.g., intersectoral committee, multi-sectoral coordination mechanisms) responsible for coordination, collaboration, and implementation? Is it based in a set of government ministries or agencies? • Does a legal or regulatory framework guide collaboration and coordination? • Which actors, disciplines, and stakeholders participate in the collaborative process? Are the micro-, meso-, and macro- governance levels represented (e.g., national, regional, local)? • To what extent does consensus exist among sectors and levels of government on the adoption, customization, and commitment to goals? • How are ideas, data, and research shared, exchanged, and delivered across relevant sectors? • How is trust fostered among the collaborators?
Management	• Has the prevalence and incidence of AMR been determined through a situational analysis? • Is a national action plan (NAP) for AMR in place, or a timeframe specified in which one will be developed and implemented? • Does the NAP contain specific, measurable, and time-bound objectives? • Does the NAP contain quantitative targets for AMR or AMU in human, environmental and animal health? • To what extent does a OH workforce strategy exist? • Are scientific and technical experts in OH engaged in the design and evaluation of the OH surveillance system to support data harmonization across sectors?
Sustainability	• To what extent have all relevant sectors entered into a written mandate or voluntary agreement to implement the surveillance system? • To what extent does an intersectoral technical advisory committee or group of subject matter experts provide ongoing support during implementation, monitoring and evaluation? • To what extent are dedicated budgets in place to implement and sustain surveillance systems? • To what extent are future budgetary needs for surveillance systems assessed? • To what extent does the funding require that the system integrates OH principles?
Accountability/ Transparency	• To what extent is a governance/management structure responsible for coordination and implementation that is accountable to the government? • To what extent do agreements exist regarding what happens should AMR surveillance objectives not be met? Is a responsible person identified in each sector? Are reprimands established? • How is accountability measured in the pertaining government body/ministry? • To what extent are mechanisms established regarding answerability? How will decision-makers answer for their activities? • To what extent are the NAP, progress reports, funding information, and surveillance reports publicly available and published regularly? • Is transparency an unofficial or legal mandate? • Is a ministry or individual responsible for ensuring transparency throughout the process? • How and where is data made accessible? • Is data reported to international surveillance systems?
Equity	• To what extent does a governance/management structure (e.g., equity, diversity, and inclusion committee) exist as part of the surveillance system? • Is there an assessment of how equitable the impacts of AMR surveillance on different AMR stakeholders are? • Is there equitable access to resources to maintain surveillance in all sectors, and to surveillance information? How is this ensured? • To what extent does the surveillance system gather information on the responsible use of, and facilitate equitable access to antimicrobials?

and depth of OH-ness of governance systems; where breadth refers to the range of actors involved in specific governance domains across human, animal, and environmental health, and depth describes how meaningful that engagement is under each governance domain.

We conceptualize the relationship between the domains as interdependent and co-constitutive, as certain qualities of a specific governance domain might also relate to a different domain and/or influence each other. For example, meaningful stakeholder participation can positively impact governance systems by fostering trust amongst stakeholders that can lead to more sustainable cooperation/collaboration and lasting participant engagement. Trust can also be generated through effective accountability practices within governance systems, conceived of as an ongoing and dynamic process informed by monitoring and evaluation. The framework is based on a logic model (Figure 2) of how qualitative aspects of a OH-informed governance system that incorporates the domains can contribute to achieving effective OH surveillance of AMR/AMU. In the figure, the inputs that facilitate OH governance principles are listed on the left (inputs to the domain), and their impacts on surveillance systems on the right (outputs of the domain, see Figure 2 below).

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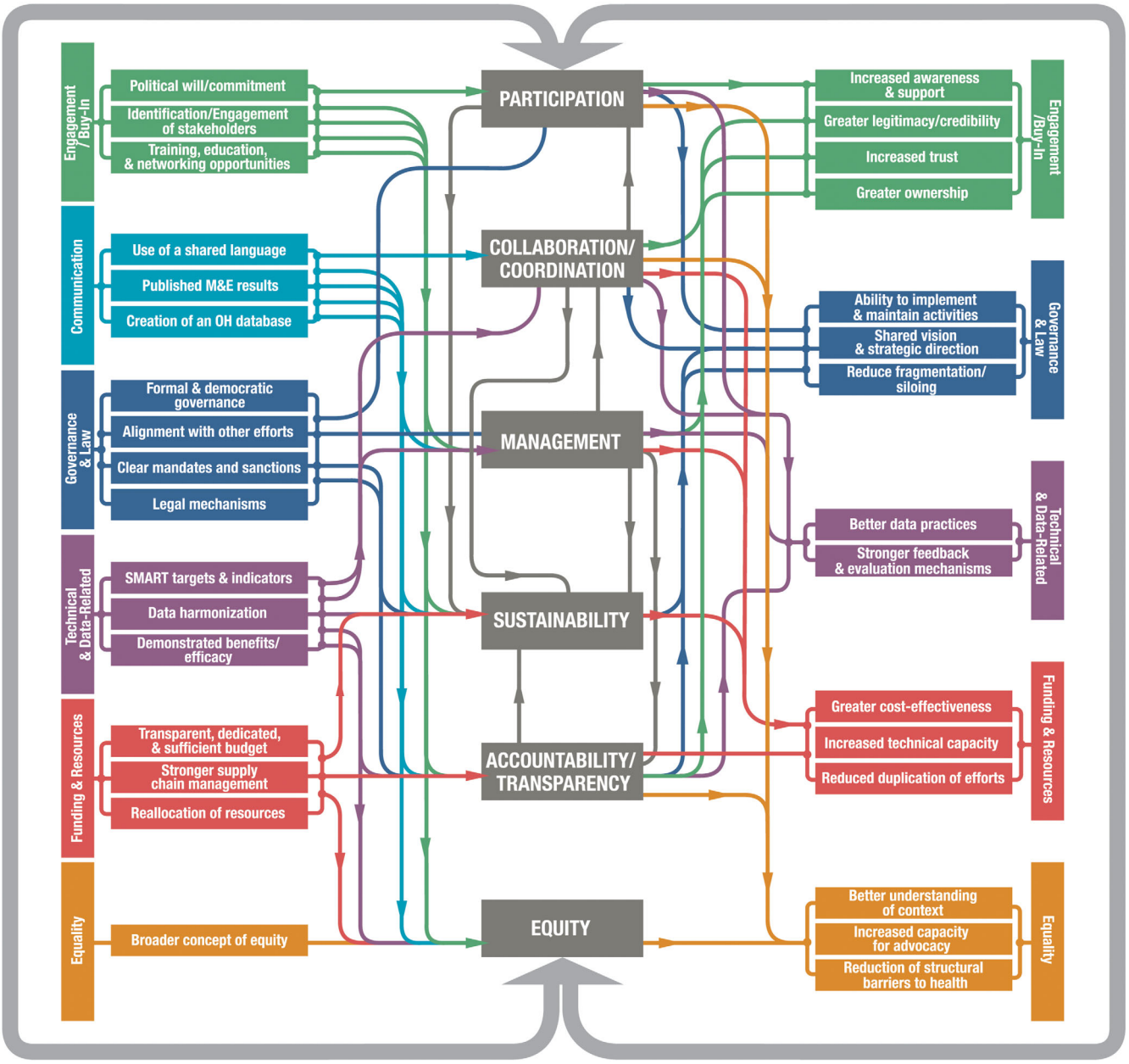

Figure 2. On the left side of the figure are inputs that facilitate implementation of the governance domains. Related inputs are organized in color-coded groups: engagement, buy-in, communication, governance and law, technical and data-related, funding and resources, and equality. In the middle are gray boxes containing the governance domains. The inputs are connected to the governance domains using arrows that are the same color as the input groups. Connections between the governance domains are represented using gray arrows. On the left side are the outputs that are facilitated by the governance domains. These outputs are grouped in the same way as the inputs (minus communication) and connected to the governance domains using arrows that are the same color as the output groups. A gray arrow that connects all the domains surrounds the entire figure.

Consideration of the facilitators/barriers that influence implementation of OH governance of AMR surveillance systems is important. To reduce silos, five barriers should be addressed: a lack of intersectoral communication, a lack of trust, siloed professional education, siloed mandates and funding, and the influence of commercial interests (Johnson et al., 2018). Adequate human and economic resources to support coordinated strategies are crucial as cost can present a barrier to collaborative surveillance, particularly for the environmental and agricultural sectors (Bordier et al., 2018; Johnson et al., 2018; Joshi et al., 2018). Training on systems thinking and community-based and participatory methods can increase the number of OH practitioners able to facilitate and coordinate transdisciplinary collaboration (dos S. Ribeiro et al., 2019; Uchtmann et al., 2015). Tertiary education should include field and cross-cultural experience to reach young professionals before they enter siloed work environments (dos S. Ribeiro et al., 2019; Uchtmann et al., 2015; Johnson et al., 2018). Epidemiological data that shows the interconnectivity of human, animal, and environmental health, and the negative impact of not addressing AMR in a cohesive intersectoral manner can increase trust and diminish resistance to change, such that collaborative surveillance is informed by evidence (Wielinga et al., 2014; Bordier et al., 2018).

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Demonstrating the economic benefit of AMR mitigation can also help to reduce the influence of commercial interests, particularly from the agricultural sector, that present a barrier to data sharing across disciplines (Queenan et al., 2016; Johnson et al., 2018; Rüegg et al., 2018; Sumpradit et al., 2021). To address conflicting priorities between risk-managers and risk-bearers, different agencies or sectors should be responsible for risk assessment and risk management (Wielinga et al., 2014).

Collaboration and coordination can also be facilitated by removing barriers to data and knowledge sharing and harmonization of protocols and data (Wielinga et al., 2014; Bordier et al., 2018; Rüegg et al., 2018; Sommanustweechai et al., 2018; Bennani et al., 2021; Chua et al., 2021; Sumpradit et al., 2021). This could be fostered through participation in regional and global surveillance networks and public-private partnerships, and via technical mechanisms such as the creation of national reference libraries, library networks, or shared laboratories that use standardized methods and a common database (Uchtmann et al., 2015; Mölstad et al., 2017; Bordier et al., 2018; Sommanustweechai et al., 2018; Bennani et al., 2021; Mader et al., 2022). Adoption of a shared vocabulary and universal guidelines, preferably available in multiple languages with widespread use, may promote data harmonization (Uchtmann et al., 2015; Iskandar et al., 2021). Agreements and frameworks for collaboration and intersectoral data sharing could reduce legal and bureaucratic barriers to data sharing, however, they must balance the obligation to safeguard informed consent and anonymity with the need for useful data (Bordier et al., 2018; dos S. Ribeiro et al., 2019; Rüegg et al., 2018). Finally, the development of an OH learning platform can support the exchange of information across borders and sectors (Wernli et al., 2020).

Discussion

Governance plays a foundational role in developing, improving, and sustaining AMR surveillance systems, given the complex nature of the emergence of AMR and the structural political-economic issues that hasten its spread (Anderson et al., 2019). As AMR is driven by interrelated dynamics in the human, animal, and environmental health sectors, strategies to address it rely on intersectoral coordination mechanisms that foster communication and collaboration across a diverse range of actors within sectoral siloes, as well as internationally. The need for an AMR governance framework informed by the OH approach was also recently noted in a review of national actions plans on AMR: "There needs to be a clear governance framework for effective development and delivery of NAPs. The ability to progress from paper to action requires governments, policy makers, and stakeholders to have clearly defined roles that are backed by financial commitment and political power to deliver objectives and review achievements" (Charani et al., 2023).

Addressing implementation facilitators and barriers to improve OH governance of surveillance is paramount. This involves diminishing silos that inhibit collaboration to better support coordination. Inputs, domains, and outputs interact through complicated pathways; improvement in one domain can foster improvement in others. Collaborative governance and meaningful intersectoral participation by a diverse group of stakeholders can foster evidence-informed policies that raise the credibility and legitimacy of initiatives and enhance buy-in and support from politicians, the public, and other pivotal actors, leading to greater sustainability. Governance domains are thus seen as interdependent, interacting with, and reinforcing each other, as the string logic model conveys. The conceptual framework and accompanying questions can be used to assess the degree to which OH principles under each domain are progressively realized when evaluating AMR surveillance systems.

The conceptual framework further addresses the limitations of existing evaluation approaches. Although 12 evaluation tools have been published to assess the governance of AMR, our conceptual model is not intended to replace them, but rather to offer an overarching framework for the governance of AMR surveillance, similar to that of Aenishaenslin et al. (2021) but from a public administration rather than a veterinary perspective. Among the 12 AMR evaluation tools available, only two (ATLASS and ISSE) focus on AMR surveillance and one was developed specifically to address OH evaluation (Bordier et al., 2019) rather than all aspects. Although Anderson et al. (2019) discussed similar domains for AMR, their approach did not specifically address AMR surveillance.

In addition, our framework includes an important domain, equity, often missing in existing discussions surrounding AMR. This includes both assessing inequitable impacts of surveillance systems on stakeholders, as well as acknowledging that the situational context to address AMR and economic circumstances differs substantially between HICs and LMICs. Currently, NAP objectives and AMR surveillance systems are typically built using evidence and standards generated in HICs, whose health resources and infrastructure experience different challenges to those in LMICs (Charani et al., 2023). Governance evaluations should be sensitive to such situational and contextual differences and realistic in what can be expected from LMICs. In addition, surveillance systems should collect data on attitudes, needs, and practicesacross socioeconomically and culturally diverse populations to understand the broad reach of policy interventions and AMR surveillance systems. This is reflective of the wider knowledge gaps surrounding the role of equity within the AMR environment and hinders reach to diverse populations, including those most clinically vulnerable to the threat of drug-resistant infections and/or most likely to be impacted by antibiotic stewardship interventions. Finally, any effective governance framework must acknowledge the role of the private sector in addressing AMR. The OH approach is an inherently whole-of-society approach and, as such, recognizes the important role of the private sector in providing data to support AMR surveillance. In the context of developing public-private surveillance partnerships, governance processes must clearly identify roles and responsibilities for the private sector and evaluate their participation over time.

Limitations of our study are that published literature synthesized involved a range of study types including empirical and theoretical research and commentary. Moreover, gray literature, comprised of government, non-governmental organizations, and multilateral secretariat reports were excluded. Studies in the English language only were synthesized, excluding contributions in other languages. Finally, given that our focus was on governance of AMR surveillance systems, other articles that do not incorporate surveillance but rather focus more generally on AMR were excluded.

Conclusion

Developing effective governance systems to guide surveillance involves addressing numerous challenges, including overcoming sectoral silos, while fostering collaboration, coordination, and trust

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across sectors, and enhancing accountable and transparent systems. Our conceptual framework can inform the design and evaluation of OH AMR governance systems, as it highlights the impact of the quality of governance within various domains and proposes a series of evaluation questions to illustrate application of the framework. Our synthesis thus usefully builds on earlier generations of research on governance of complex AMR issues. In addition, our synthesis can also offer insights on how to address governance systems beyond AMR, as many of the barriers and facilitators identified can be used to inform OH governance of different but similarly complex health challenges.

Global dimensions of AMR surveillance are important to factor in as well. Creative global approaches to generate funds for sustainable surveillance, particularly in LMICs, are imperative. International contributions to such agencies as the WHO, the Fleming Fund, and a Global Antimicrobial Conservation Fund may enhance OH surveillance capacity in LMICs along with the research and diagnostics needed to advance bacteriology. International legal treaties with enforceable sanction mechanisms could further enhance accountability (Munkholm and Rubin, 2020). Governments and organizations involved in the creation of AMR surveillance systems could learn from the Paris Climate Agreement, which set country-specific binding responsibilities, subject to external and independent review, with annual meetings and periodic scientific reviews (Rogers Van Katwyk et al., 2020). Incorporating AMR in the Pandemic Treaty by identifying explicit global targets for reducing AMR by a specific date could likewise foster more robust governance mechanisms to guide surveillance (FAO et al., 2023).

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/one.2023.13

Data availability statement. The authors confirm that the data supporting the findings of this study are available within the article [and/or its supplementary materials].

Author contribution. A.R., F.H., and M.E.W. contributed to the development of the research concept and design, data collection and interpretation, and writing and revising the manuscript. C.A., R.A., A.B.-L., L.P.C., R.L., I.L., and E.J.P contributed to the development of the research concept and design and revisions. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Financial support. The research that led to the development of our conceptual framework was financially supported by a Seed Grant from the Global 1 Health Network as well as funding through the Joint Programming Initiative on AMR as part of the Convergence in evaluation frameworks for integrated surveillance of AMR, CoEval-AMR PHASE 2.

Competing interests. None.

Ethics statement. Not applicable.

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https://doi.org/10.1017/one.2023.13 Published online by Cambridge University Press