



The Contribution of One Health Approaches to The Mitigation of Zoonotic Disease Outbreaks: Review

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Abstract

Background: The emergence and spread of zoonotic diseases represent a significant global health challenge, responsible for millions of infections and deaths annually. Zoonoses, primarily transmitted from animals to humans, account for approximately 60% of recognized infectious diseases and a substantial portion of emerging infectious diseases (EIDs). This review highlights the multifactorial nature of zoonotic disease emergence, including environmental, ecological, and anthropogenic factors.

Methods: A comprehensive literature analysis was conducted to evaluate existing monitoring systems and the effectiveness of One Health approaches that integrate human, animal, and environmental health sectors.

Results: The findings indicate that current surveillance frameworks are often fragmented, leading to delayed responses and inadequate management of outbreaks. Effective monitoring requires robust intersectoral collaboration and the establishment of real-time data-sharing mechanisms. The study underscores the importance of proactive risk assessment and community engagement in enhancing surveillance systems. Moreover, it emphasizes the need for evidence-based prevention strategies that address the root causes of zoonotic spillover events.

Conclusions: In conclusion, a cohesive One Health framework is essential for improving preparedness and response to zoonotic disease outbreaks. By fostering collaboration among public health, veterinary, and environmental professionals, this integrated approach can significantly mitigate the risks posed by zoonotic diseases and enhance global health security. Future research should focus on developing standardized protocols for monitoring and rapid response, alongside investment in technology-driven solutions such as artificial intelligence.

Keywords: One Health, zoonotic diseases, surveillance systems, public health, disease prevention.

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1. Introduction

A significant global issue that is well-recognized is the proliferation of infectious diseases. Zoonoses, illnesses that may be naturally transferred from animals to people, are responsible for 2.5 billion infection cases and 2.7 million deaths annually, including 60% of recognized infectious diseases and up to 75% of emerging infectious diseases (EIDs) [1]. The catalog of zoonotic illnesses is comprehensive and always changing, with coronavirus disease 2019 (COVID-19) being the most recent addition [2]. As of mid-2023, the COVID-19 pandemic had caused the death of 6.9 million individuals. The COVID-19 pandemic has highlighted the essential need to enact evidence-based multisectoral strategies to prevent, identify, and alleviate the effects of emerging infectious diseases (EIDs). This urgency stems not just from present dangers but also from past antecedents [3]. Historically, zoonotic pathogen spillover has resulted in significant epidemics. Instances of zoonotic outbreaks in the 21st century encompass severe acute respiratory syndrome (SARS), the H5N1 variant of highly pathogenic avian influenza (HPAI), swine flu (H1N1), Middle East respiratory syndrome (MERS), Zika, Ebola, Nipah, and COVID-19, all of which present significant threats to human health and, in certain instances, have also impacted animal health due to their zoonotic characteristics.

Comprehending the fundamental reasons and sources of zoonotic epidemics is essential to reduce the risk of disease transmission, especially in light of the increasing frequency of such outbreaks over time. A multitude of factors, including international trade and travel, intensive animal husbandry, rising demand for animal products, ecological disturbances, wildlife exploitation, antimicrobial resistance (AMR), deforestation, climate change, global warming, and ecotourism, have collectively contributed to the emergence of significant global public health challenges [4].

The proliferation of agriculture has encroached onto animal habitats, disrupting ecosystems and facilitating closer interactions between people, livestock, and wildlife, as well as disease vectors, hence possibly increasing the danger of zoonotic pathogen transmission via sylvatic cycles [5]. The danger of zoonotic disease transmission at the environment-wildlife interface is exacerbated by human activities, including hunting and consumption of game meat, wildlife trading, and the exploitation of animal parts for commerce [6,7]. Moreover, inappropriate antibiotic use in livestock farming intensifies the worldwide problem of antimicrobial resistance (AMR). By 2050, as many as 10 million lives may be lost worldwide due to antimicrobial resistance (AMR)-related diseases, with the economic impact of AMR projected to reach USD 100 trillion from 2015 to 2050 [8-10].

The rise of zoonoses in our globalized environment, shaped by continuous human activity, highlights the need for effective monitoring systems. Identifying risk indicators is essential for pinpointing potential hotspots, and resolving these issues requires evidence-based solutions and data-driven decision-making. An expedited cross-border response that surpasses geographical and political boundaries is essential, with efficient communication serving as a crucial element to effectively link stakeholders, healthcare professionals, and the public [11,12].

This study thoroughly evaluates the current monitoring systems for zoonotic diseases, taking into account the difficulties and context. It offers a summary of international organizations involved in monitoring zoonotic epidemics and delineates the critical elements necessary at the human-animal-environment interface for developing comprehensive surveillance networks. This study aims to improve understanding of zoonotic dynamics and assist in the formulation of appropriate monitoring techniques to protect global public health.

2. Socio-economic impact of developing zoonoses

Since 1980, around 87 novel vectors and zoonotic infectious illnesses have been recorded [1]. These EIDs represent 26% of yearly worldwide mortality, including several groups of pathogens. Viruses,

including prions, constitute 37% of developing and re-emerging diseases, while protozoa represent 25% [13]. Viruses are the predominant causal agents of the majority of new and re-emerging illnesses. The influence of infectious illnesses surpasses mortality, resulting in a significant loss of disability-adjusted life years (DALYs), which accounts for about 30% of the 1.49 billion DALYs lost each year [14,15].

Zoonotic illnesses substantially affect the world economy. Outbreaks occurring from 1997 to 2009, such as Nipah (Malaysia), West Nile fever (USA), SARS (Asia, Canada), HPAI (Asia, Europe), bovine spongiform encephalopathy (United Kingdom), and Rift Valley fever (Tanzania, Kenya, Somalia), incurred an estimated economic cost of around USD 80 billion [16]. Furthermore, some estimates suggest that emerging infectious diseases (EIDs) have incurred direct costs beyond \$100 billion over the last twenty years, with possible pandemic scenarios leading to losses in the billions of dollars [17]. The International Livestock Research Institute (ILRI) recognizes zoonotic diseases as a significant influence on the livelihoods of one billion livestock keepers, causing 2.7 million human deaths and nearly 2.5 billion instances of human sickness each year [18].

Moreover, in resource-constrained areas, about one in seven animals are projected to be impacted by these zoonoses [19]. Considering the significant socioeconomic consequences linked to zoonotic outbreaks, authorities have to prioritize expenditures in a comprehensive strategy focused on disease prevention instead of depending only on response measures [17,20,21]. The continual appearance of novel EIDs presents a sustained danger to the integrity of the healthcare system and may impede economic growth unless comprehensive mitigation techniques are developed [6,9,22]. Overcoming these challenges necessitates significant investment in infrastructure development, including early disease detection capabilities, integrated laboratory testing facilities, comprehensive surveillance systems, vaccine production, and the incorporation of artificial intelligence to proactively mitigate zoonotic risks [23-25].

The World Health Organization (WHO) has delineated a set of guidelines for national preparation. These include the enhancement of public health infrastructure, the fortification of risk communication mechanisms, the boosting of epidemic preparation and response systems, the advancement of research and its practical application, and the advocacy for political commitment and collaborative partnerships [26,27]. These methods together provide a proactive framework to mitigate the effects of emerging zoonotic diseases on healthcare and socioeconomic systems.

3. Prioritizing the monitoring of zoonotic diseases

The range of zoonotic illnesses, including both longstanding ailments like rabies and current epidemics such as COVID-19, continues to grow. The emergence of zoonotic diseases generally follows a phased progression, beginning with initial spillover events from animal reservoirs to humans, followed by sporadic small-scale outbreaks among human populations, and concluding with pathogen adaptation for sustained human-to-human transmission. Each of these sequential stages may be influenced by unique underlying causes, requiring customized, context-specific management mechanisms [28].

When developing zoonoses transition to an endemic form, they continuously impact both human and animal populations while also presenting a persistent danger of future epidemic revival if circumstances favorable to rapid transmission are reestablished. An alarming insight derived from the EIDs trend is that the incidence of zoonotic outbreaks is not expected to diminish in the foreseeable future. This is particularly evident given the increasing human and animal populations with significant changes in the natural landscape, including biodiversity loss [29].

The need for effective monitoring in combating zoonotic infections is paramount worldwide. Surveillance consistently produces essential data that support strategic initiatives to restrict, control, and mitigate the effects on vulnerable human and animal populations [30]. Early diagnosis is crucial for containing diseases at their source, a demand heightened by the modern global population movement. Moreover, early identification is crucial for preventing life-threatening diseases, including Zika, Nipah, Ebola, and yellow fever [31]. Prompt illness identification by surveillance, along with rapid implementation

of responsive measures, may significantly reduce the scale, intensity, and economic impact of emergency outbreak responses [32].

Addressing zoonotic illnesses is a unique challenge, requiring focused consideration of the processes contributing to their development. The complex interaction between ecosystems and human activities increases the likelihood of disease transmission from animals to people [33]. Consequently, monitoring systems must clarify the critical function of certain animal species in connecting wildlife reservoirs to human populations, thereby facilitating targeted actions. Numerous zoonoses are marked by their insidious characteristics, often presenting as asymptomatic or subclinical in both animal hosts and human carriers, thereby enabling subtle transmission and covert spread [34]. The COVID-19 pandemic has shown that asymptomatic persons serve as carriers, facilitating the fast spread of the virus. Thus, monitoring systems that can detect asymptomatic or mildly symptomatic carriers are crucial for prompt containment [35].

A comprehensive scientific foundation is necessary to improve our capacity to forecast and execute preventive strategies against zoonotic disease epidemics. This paradigm should include rigorous data collecting and thorough comprehension of the complexities of illness onset and transmission. This offers comprehensive insights into the genetic, demographic, sociocultural, and ecological factors that enable the spread of zoonotic viruses to humans. These scientific methodologies are essential for formulating a comprehensive plan for the early identification and containment of outbreaks, hence improving readiness to foresee, avert, and address future zoonotic disease risks [33].

4. Evaluation of the current surveillance system/continuing surveillance methodology

Efficient public health methods for monitoring and controlling emerging diseases depend significantly on surveillance systems [10]. This entails the implementation of event- and indicator-based surveillance, the augmentation of laboratory capacities in both human and animal domains, the assurance of a proficient epidemiological staff, and the establishment of effective communication systems [34]. Surveillance systems are generally managed by various national departments or ministries, including human infectious disease surveillance within health departments, food and animal disease surveillance under agriculture or livestock departments, and wildlife disease surveillance through natural resources, wildlife, and aquaculture departments. Additionally, several food production enterprises engaged in cattle rearing for global commerce have implemented monitoring measures [35]. Although companion animals may contribute to zoonotic disease transmission, their monitoring is often performed as specialized research and typically lacks assigned departmental oversight in the majority of nations [36].

Worldwide, several disease monitoring systems and networks have been built, mostly focused on identifying new zoonotic illnesses in both human and animal populations. Prominent human disease monitoring systems include the WHO Global Outbreak and Response Network (GOARN) and the U.S. The Department of Defense's monitoring programs are enabled by the Global Emerging Infection Monitoring and Response System. These initiatives, especially those focused on high-risk areas in Africa, the Middle East, and Southeast Asia, are crucial for the rapid detection of zoonotic illnesses [37].

Additional initiatives that engage closely with communities to enhance zoonotic disease surveillance efforts comprise the PREDICT project, financed by the United States Agency for International Development (USAID), and the Global Early Warning and Response System for significant animal diseases, including zoonoses (GLEWS+), a collaborative initiative by the Food and Agriculture Organization (FAO), World Organization for Animal Health (WOAH), and the World Health Organization (WHO). These efforts provide extensive training for field and laboratory professionals, including both human and animal health sectors [38]. The primary aim of the PREDICT initiative is the rapid identification of emerging new viral hazards to human and animal health. These approaches concentrate on identifying previously unrecognized illnesses and enhancing the ability to evaluate risks and control epidemics that might escalate into pandemics [39]. GLEWS+ aims to enhance preventative and control strategies via the swift identification and evaluation of health hazards and potential issues at the human-animal-ecosystem interface. Alerts on animal epidemics may serve as direct early warnings for zoonotic occurrences, facilitating the improvement of human surveillance and the execution of preventative measures [16].

Human monitoring systems have successfully detected many zoonotic disease outbreaks in human populations. Nonetheless, the worldwide ability to swiftly identify illnesses in animal populations, especially wildlife, and prevent transmission to people is still constrained [40]. Disease monitoring programs for livestock, poultry, and wildlife sometimes lack cohesive management and have traditionally been underfunded relative to human surveillance activities [41]. Thus, it is often the detection of disease outbreaks in people that prompts the later identification of outbreaks in animal populations, rather than a proactive strategy where animal monitoring acts as an early warning system for possible human infections.

To alleviate the detrimental impacts of biological threats, including both accidental and intentional dissemination of pathogenic or poisonous substances, the global community established a legally enforceable framework known as the 'International Health Regulations 2005' (2005). The successful implementation of the WHO's International Health Regulations requires proactive involvement from the animal health sector of each country. The WOAAH provides the Performance of Veterinary Services (PVS) route for the animal sector, a thorough framework that allows nations to do detailed evaluations of their veterinary services and pinpoint areas for improvement [42-45].

Utilizing the insights and results obtained from the assessment and gap analysis tools employed in the IHR monitoring framework and the WOAAH PVS pathway, WHO and WOAAH have collaboratively developed methodologies to enhance cross-sectoral communication between animal health and human health. This advanced discourse improves operational coordination and provides policymakers with more thorough insights to inform strategic investments in surveillance and monitoring programs, eventually bolstering readiness to manage the spillover and dissemination of zoonotic diseases [46,47].

5. Comprehending disease pathways and surveillance interrelations

To improve our ability to forecast and effectively address disease outbreaks, it is crucial to investigate the complex biological routes of illnesses and the conceptual interconnections across human, animal, and environmental monitoring sectors. These interactions are crucial in averting the onset of illnesses. There are often six main phases (Fig. 1) that influence the dynamics of illness in human and animal populations. The dynamics of disease are inherently connected to different stages of zoonotic transmission.

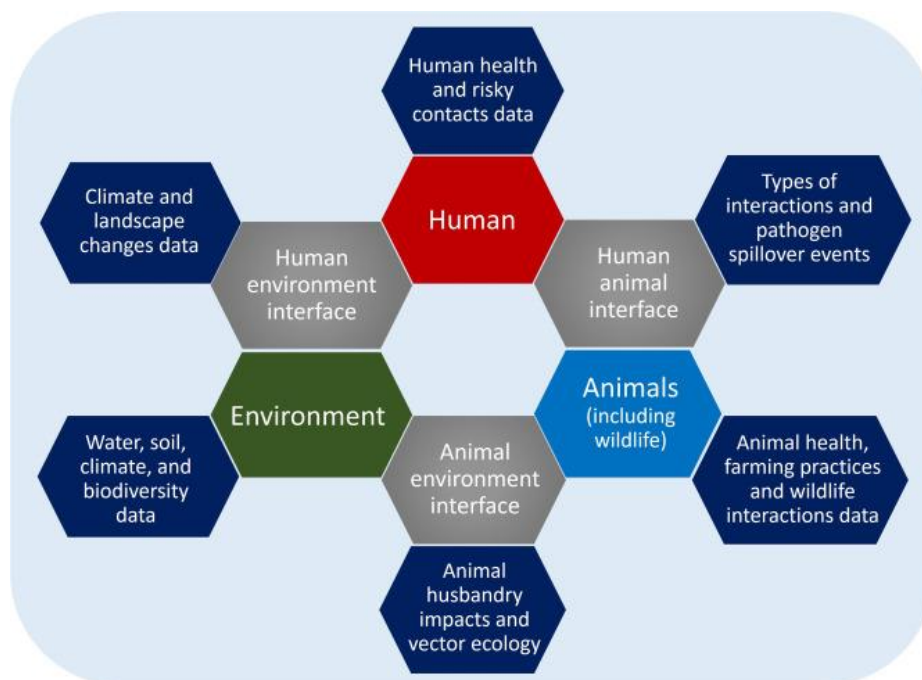


Figure 1. Elements of the human animal–environment interaction should be evaluated in the design of surveillance networks.

As the illness advances in human and animal populations, the objectives of disease mitigation and monitoring adapt correspondingly. An efficient surveillance system is essential for detecting the emergence of diseases in animals before their spillover into human populations, during localized human infections caused by spillovers, or at the phase of sustained human-to-human transmission of zoonotic threats. Each phase requires specialized public health and animal disease control goals, along with customized treatments and monitoring strategies aimed at the impacted and at-risk groups. This flexibility is based on the creation of a risk profile for public health in each situation, including factors such as the characteristics of the pathogen and possible exposure routes. The importance of information obtained via monitoring at different phases depends on the defined risk profile [48,49].

6. Requirement for multisectoral cooperation in zoonotic disease surveillance

Establishing a successful zoonotic disease monitoring system necessitates the promotion of evidence-based multisectoral cooperation with clearly defined roles and responsibilities. These collaborations may substantially diminish the effects of illnesses on people and animals, as well as alleviate social and economic repercussions at the household, regional, and national levels [50].

The recent COVID-19 epidemic has highlighted the need for efficient multisectoral collaborations. Human, cattle, wildlife, and environmental health must be considered together under the One Health paradigm [51]. Multisectoral collaborations must be customized to address unique requirements and available resources since health is a community endeavor dependent on professional confidence and the exchange of experience. The UNEP and ILRI underscore the need for a multisectoral coordinated strategy for the management and prevention of zoonotic disease outbreaks and pandemics at the intersections of human, animal, and environmental domains [52]. National authorities are required to collaborate with relevant ministries to swiftly identify significant public health occurrences, as mandated by international health standards.

Effective coordination and collaborative endeavors must include several sectors and be begun for specific zoonotic diseases prioritized via equitable contributions from all stakeholders [53]. Prioritization is essential for resource allocation and guarantees efficient consumption [54]. Integrating disease prioritizing methodologies with seroprevalence investigations facilitates the identification and targeting of priority zoonotic illnesses in particular locations, hence enhancing the efficiency of preventative and control actions. Efficient prioritizing also facilitates the enhancement of laboratory capabilities and the building of a resilient surveillance network. It is important to emphasize that the socioeconomic effects of zoonotic illnesses might vary over time and between regions and are often underestimated in resource-constrained settings due to insufficient monitoring and awareness [28].

The CDC's One Health office has developed the One Health Zoonotic Disease Prioritization tool to identify high-priority zoonoses necessitating multidisciplinary collaboration. This tool utilizes a semiquantitative method to guarantee equitable involvement from all pertinent sectors, even in the absence of reliable surveillance data [55,56]. This tool convenes a varied panel of specialists from human, animal, environmental, and other relevant fields. They collaboratively construct criteria that may be customized for individual locations or nations and classify zoonotic illnesses of considerable national or regional importance [57,58]. This approach has been effectively used in several countries to emphasize zoonotic illnesses for prospective engagement initiatives under the GHSA action package for zoonotic diseases [59].

7. Enhancement of human capabilities for intersectoral cooperation

The implementation of a comprehensive zoonotic disease surveillance system necessitates collaboration at regional, national, and global levels among experts from various disciplines, including clinical diagnosis, field epidemiology, laboratory sciences, social sciences, ecology, and information technology [60]. A proficient team must possess strong management abilities, comprehend the need for a nationally and internationally connected system, and have the capacity to interact successfully with specialists from many disciplines. Collaboration between public and private sector entities in the domains of human health, agriculture, and natural resources is essential. This includes doctors, public health experts,

community health workers, labs, hospitals, and NGOs focused on health education, communication, and training within the human health sector. The agricultural, livestock, and poultry sectors include veterinarians, community animal health workers and technicians, animal producers, veterinary clinics, and NGOs providing development and capacity-building initiatives for small-scale livestock and poultry farmers. Initiatives about wildlife conservation, management, and disease surveillance are essential.

Throughout the years, professionals like doctors, nurses, veterinarians, animal technicians, and laboratory scientists have been instrumental in the early identification of developing zoonotic illnesses, as shown by the prompt diagnosis of the monkeypox virus in 2022 [61]. Delivering extensive in-person practical training to address zoonotic infections in human and animal populations is crucial, especially for uncommon, sporadic, and newly developing illnesses. The use of information technology for training shows potential; nevertheless, more development and assessment of these tools are required to confirm their efficacy.

8. Utilizing artificial intelligence (AI) for pandemic preparation and response

Following the proclamation of the COVID-19 pandemic, the WHO and other health organizations acknowledged the potential of AI as a significant resource for managing the pandemic and planning for future health emergencies. AI-driven early warning systems are essential for evaluating real-time data from diverse sources, including digital content and communication channels, to identify trends that signal future epidemics. These systems provide prompt notifications that may assist in surveillance, healthcare network administration, and data analysis. Prominent examples are the WHO Early Warning System and Bluedot [62,63]. Numerous nations already use geolocation data, security camera recordings, credit card information, and contact tracking technologies to ascertain probable infection routes [64]. In some circumstances, AI may retrieve epidemiological data more swiftly than traditional health data reporting techniques [65]. Continuous technology breakthroughs provide significant potential for the welfare of both humans and animals, highlighting that the incorporation of AI into existing research frameworks may be crucial in averting future pandemics [26].

Multiple parameters must be analyzed to evaluate the efficacy of disease surveillance systems. These encompass timeliness (in detection, confirmation, and dissemination), simplicity (user-friendliness), flexibility (adaptation and responsiveness to changing circumstances, emerging threats, and evolving data requirements), data quality, reliability, acceptability, sensitivity (the capacity to identify all disease cases or outbreaks), positive predictive value (indicating the probability that reported outbreaks are authentic), representativeness of the at-risk population, stability (the system's resilience under adverse conditions), and overall utility [32,66]. In the realm of animal disease monitoring and surveillance systems, the essential criteria for efficacy encompass clarity regarding objectives, sampling methodologies, coordination and awareness, environmental considerations, screening and diagnostic protocols, data collection and transmission processes, data processing and analytical capabilities, and mechanisms for information dissemination [65]. Enhancing farmers' awareness to promote identification and self-reporting is crucial for the efficacy of passive data collecting, especially in resource-constrained environments.

9. Conclusions

The persistent introduction of novel zoonotic diseases is a continual challenge, requiring the constant enhancement of disease monitoring systems to proactively prevent and control outbreaks. This objective requires a steadfast commitment at both national and international levels to implement an effective monitoring system. Effective leadership and collaborative synergy across several stakeholders, including health, agriculture, natural resources, and education, are essential components of this collective endeavor. These initiatives must surpass geographical barriers and unify nations and regions. Moreover, financial backing and dedication are crucial not only for the establishment of the system but also for its ongoing functionality. The continuous examination and review of surveillance systems spanning human, animal, and linked domains are essential for adjusting to emerging dangers. This thorough assessment must include essential factors, such as the extent and quality of surveillance, the efficacy of multisectoral cooperation, and other vital aspects. Global entities like the WHO, FAO, and WOAH have initiated efforts to enhance and

evaluate existing global monitoring methods; nonetheless, efficient national and regional data integration is crucial for the overall efficacy of zoonotic disease surveillance systems.

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مساهمة نهج "الصحة الواحدة" في التخفيف من تفشي الأمراض الحيوانية المنشأ: مراجعة

الملخص

الخلفية: تمثل ظهور وانتشار الأمراض الحيوانية المنشأ تحديًا كبيرًا للصحة العالمية، حيث تتسبب في ملايين الإصابات والوفيات سنويًا. تشكل الأمراض الحيوانية المنشأ، التي تنتقل بشكل أساسي من الحيوانات إلى البشر، حوالي 60% من الأمراض المعدية المعترف بها ونسبة كبيرة من الأمراض المعدية الناشئة (EIDs). تبرز هذه المراجعة الطبيعية متعددة العوامل لظهور الأمراض الحيوانية المنشأ، بما في ذلك العوامل البيئية، والبيئية، والبشرية.

الطرق: تم إجراء تحليل شامل للأدبيات لتقييم أنظمة المراقبة الحالية وفعالية نهج "الصحة الواحدة" الذي يدمج قطاعات الصحة البشرية، والحيوانية، والبيئية.

النتائج: تشير النتائج إلى أن الأطر الحالية للمراقبة غالبًا ما تكون مجزأة، مما يؤدي إلى استجابات متأخرة وإدارة غير كافية للتفشي. تتطلب المراقبة الفعالة تعاونًا قويًا بين القطاعات المختلفة وإقامة آليات تبادل بيانات في الوقت الحقيقي. تسلط الدراسة الضوء على أهمية تقييم المخاطر بشكل استباقي ومشاركة المجتمع في تعزيز أنظمة المراقبة. علاوة على ذلك، تؤكد الحاجة إلى استراتيجيات وقائية قائمة على الأدلة تعالج الأسباب الجذرية لحدوث أحداث تسرب الأمراض الحيوانية المنشأ.

الاستنتاجات: في الختام، فإن وجود إطار متماسك للصحة الواحدة أمر ضروري لتحسين الجاهزية والاستجابة لتفشي الأمراض الحيوانية المنشأ. من خلال تعزيز التعاون بين محترفي الصحة العامة، والطب البيطري، والبيئية، يمكن أن يقلل هذا النهج المتكامل بشكل كبير من المخاطر التي تشكلها الأمراض الحيوانية المنشأ ويعزز الأمن الصحي العالمي. ينبغي أن تركز الأبحاث المستقبلية على تطوير بروتوكولات موحدة للمراقبة والاستجابة السريعة، بالإضافة إلى الاستثمار في الحلول المعتمدة على التكنولوجيا مثل الذكاء الاصطناعي.

الكلمات المفتاحية: الصحة الواحدة، الأمراض الحيوانية المنشأ، أنظمة المراقبة، الصحة العامة، الوقاية من الأمراض.