Review Articles

From Hantavirus to the Next Pandemic: Structural Barriers to Translating "One Health" from Aspiration to Implementation

*Yuhao Zhang [a], Liwen Chen [b], Ruirong Zeng [c]**

[a] *Jinan University, No. 601, Huangpu Avenue West, Guangzhou 510632, China*
[b] *Guangzhou Medical University, No. 195, Dongfeng West Road, Guangzhou 510182, China*
[c] *Department of Infectious Diseases, Guangzhou Third People's Hospital, No. 63 Huadi Avenue South, Liwan District, Guangzhou 510375, China*

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ABSTRACT

Objective: Globally endorsed for tackling zoonotic and emerging infections, the One Health framework faces major structural gaps between policy and practice. This study explores its implementation barriers across governance, funding, technology, workforce and community aspects via hantavirus cases, and evaluates related risks of Disease X outbreaks. **Methods:** Critical policy analysis and case study were conducted, drawing on hantavirus research in Latin America and the Caribbean, existing reviews on One Health challenges, and literature on Disease X preparedness in resource-limited regions. **Results:** Systemic flaws pervade One Health execution: fragmented cross-sector governance and budgets, insufficient preventive funding, poor data interoperability and unequal genomic surveillance capacity. Segmented professional training hinders interdisciplinary collaboration, while top-down strategies and local cultural misunderstandings reduce public cooperation. Multiple field cases further prove the framework's operational fragmentation. **Conclusion:** Hantavirus exposes deep structural defects of One Health. To move beyond empty policy advocacy and prevent future pandemics, cross-sector coordination, unified budgeting, community-involved surveillance, and equitable data governance must be established worldwide.

1. Introduction

In May 2026, the Antarctic expedition cruise ship MV Hondius experienced an outbreak of Andes hantavirus (ANDV), resulting in multiple severe and fatal cases. This event not only exposed the vulnerability of zoonotic disease transmission in confined spaces and global travel networks, but more fundamentally revealed the structural dysfunction of traditional prevention and control systems when confronted with multi-interface, cross-sectoral risks: virological surveillance, travel medicine, environmental engineering, International Health Regulations (IHR) enforcement, and cruise line corporate governance lacked effective coordination mechanisms.

As a prototypical zoonotic pathogen, hantavirus transmission risk is nested within multiple interfaces of rodent ecology, climate change, agricultural landscapes, and human behavior. In the Old World (Eurasia), hantaviruses primarily cause hemorrhagic fever with renal syndrome (HFRS), while in the New World (the Americas), they cause hantavirus pulmonary syndrome (HPS/HCPS) with case fatality rates reaching 30%–50%. ANDV is the only known hantavirus strain with documented limited human-to-human transmission. Nevertheless, prevention and control efforts have long been confined to a binary technical pathway of "rodent control plus health education," neglecting the systemic drivers embedded in ecology, climate, and sociocultural contexts [1].

The One Health concept, which emphasizes the indivisibility of human, animal, and ecosystem health, has been elevated to the core paradigm of global health policy by the Quadripartite alliance of WHO, FAO, WOAH, and UNEP. However, despite high-level policy endorsement, institutionalization at the operational level has progressed slowly. The Lancet One Health Commission notes that achieving genuine One Health governance requires global-scale reorientation of values, reconfiguration of interests, redistribution of resources, and reallocation of power. Current challenges include initiative fragmentation, lack of a coordinated strategic direction, underrepresentation of low- and middle-income countries (LMICs) and marginalized communities, structural collaboration barriers (including insufficient cross-sectoral funding), and monitoring and evaluation gaps.

* *Corresponding author: Ruirong Zeng*
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The central argument of this study is that hantavirus should not be viewed merely as an epidemiological problem to be "solved," but rather as a "diagnostic lens" through which to examine the deep structural barriers encountered in the translation of One Health from concept to practice. These barriers not only constrain current effective prevention of hantavirus, but also constitute institutional vulnerabilities in preparedness for "Disease X"—the next pandemic.

2. Theoretical Framework: What Are "Structural Barriers"?

2.1. Conceptualizing Structural Barriers

This study draws on the concept of "structural barriers" from public health policy analysis, referring to systemic constraints embedded in institutional arrangements, resource allocation, power relations, and cultural cognition—rather than individual-level knowledge deficits or technical inadequacies. These barriers possess four characteristics:

1.Embeddedness: Deeply rooted in bureaucratic systems, legal frameworks, and professional socialization processes;

2.Interactivity: Barriers across different dimensions reinforce each other, forming a "barrier matrix";

3.Path Dependency: Historically formed institutional arrangements possess self-sustaining tendencies;

4.Scalar Nesting: Barriers at multiple scales—from global governance to community practice—mirror and reinforce one another.

2.2. Analytical Dimensions

Based on a systematic review of One Health implementation barriers [2], this study categorizes structural barriers into five interrelated dimensions:

- Governance and Institutional Dimension: Sectoral silos, political will deficits, legal authorization gaps, and coordination mechanism failures;
- Financing and Resource Dimension: Reactive outbreak-dependent financing, rigid sectoral budget boundaries, and sustainability deficits;
- Data and Technology Dimension: Data silos, interoperability failures, genomic surveillance inequity, and digital divides;
- Workforce and Capacity Dimension: Disciplinary separation, absence of shared competency models, and misaligned incentive structures;
- Community and Cultural Dimension: Top-down technocratic approaches, indigenous knowledge exclusion, cultural belief conflicts, and trust deficits.

The following sections dissect these barriers layer by layer, integrating hantavirus case evidence with global findings.

2.3. Methodological Reflection: Case Selection Criteria and Generalizability

This study employs a combined methodology of critical policy analysis and in-depth case description. Case selection followed three criteria:

(1) Theoretical Relevance: Cases must map onto at least two One Health barrier dimensions, revealing mechanisms of interaction and reinforcement. The hantavirus transmission chain in Latin America and the Caribbean simultaneously involves ecological-climate (data/governance), agricultural-health sectoral divides (governance/financing), and community cultural cognition (culture/workforce) interfaces.

(2) Geographic and Institutional Diversity: Selected cases cover different governance architectures and resource levels. Panama represents rural epidemic zones in LMICs, with ethnonursing data revealing community-level cultural barriers; Grenada represents small island developing states (SIDS), highlighting external dependency and governance vacuums; global genomic surveillance inequity reveals North-South structural disparities.

(3) Data Accessibility and Triangulation: Priority was given to cases supported by systematic reviews, ethnographic field investigations, and international agency policy analyses, ensuring cross-source triangulation. The Stanford Grenada pilot, the Panama ethnonursing field study, and the Lancet One Health Commission report constitute a multi-source evidentiary base.

It should be noted that this study does not aim for statistical representativeness, but rather identifies structural patterns that recur across diverse contexts through "maximum variation case" description. The generalizability of these patterns lies not in statistical frequency, but in the cross-contextual applicability of their institutional logics—sectoral governance, reactive financing, and data silos recur with varying intensity across countries and disease contexts, constituting the "deep grammar" of One Health implementation failures.

3. Governance and Institutional Barriers: The "Iron Cage" of Sectoralization

3.1. Triple Fragmentation: Data, Budget, and Decision-Making

The core premise of One Health is cross-sectoral collaboration, yet the fundamental architecture of global health governance is organized by species/sector. Human health, agriculture (veterinary), and environmental sectors maintain separate administrative systems, databases, surveillance networks, and budget streams—so-called "sectoral silos" [3].

In hantavirus prevention, this fragmentation manifests as data fragmentation: human hantavirus case reporting falls under health ministries, rodent host surveillance under agriculture/veterinary ministries, and habitat change and climate data under environmental/meteorological agencies. A systematic review in Latin America showed that most climate-association studies rely on global climate databases rather than local meteorological data, and lack longitudinal monitoring of rodent population density and virus prevalence [4]. Consequently, when public health decision-makers attempt to understand outbreak drivers, integrated eco-epidemiological data are unavailable.

Decision fragmentation is equally severe. In rural Panamanian hantavirus-endemic areas, agricultural fumigation policies are formulated by agricultural ministries, housing sanitation standards by health ministries, and deforestation and land-use planning by environmental/planning ministries. Community members' cultural misconception attributing hantavirus to pesticide fumigation partly stems from the institutional disconnect between agricultural policy and public health risk communication [5].

Response fragmentation was starkly illustrated by the 2026 MV Hondius ANDV outbreak, where coordination among the cruise line, flag state, port state, passengers' countries of origin, and the Antarctic Treaty system exposed the absence of cross-sectoral, cross-jurisdictional response mechanisms in international health governance.

3.2. Deficits in Political Will and Legal Authorization

A PRISMA-compliant systematic review of One Health implementation barriers in developing countries identified "lack of political will, weak governance, and shortages of human, financial, and logistical resources" as the foremost barriers. In multi-country African cases, the absence of national One Health coordination bodies, lack of legal frameworks for cross-sectoral collaboration, and tensions between ministerial priorities create zero-sum dynamics [2].

WOAH's policy reflection report further notes that effective One Health implementation is hindered at structural, organizational, and individual levels. Structurally, fragmented governance frameworks and financing mechanisms constrain cross-sectoral coordination; organizationally, rigid institutional mandates and sector-specific accountability structures inhibit collaboration and shared credit. The Lancet Commission emphasizes that current global One Health initiatives suffer from "fragmentation"—numerous projects run in parallel without unified strategic direction. Although the Quadripartite mechanism exists, it lacks sufficient resources, dedicated personnel, and legal authority to fulfill global governance functions.

3.3. Grenada's "No-Man's-Land"

The Caribbean has long been a blind spot in hantavirus research. The Stanford Center for Innovation in Global Health-funded One Health pilot in Grenada represents the first comprehensive hantavirus ecology and disease burden investigation in the Caribbean, conducted jointly by WINDREF and the School of Veterinary Medicine. Yet this study precisely reveals the governance vacuum: in a small island developing state, the human health department lacks animal host surveillance capacity, the agriculture department lacks virological diagnostic capacity, and the environmental department lacks epidemiological perspectives—with no institutionalized coordination platform among them. The study's success depended on temporary external academic intervention rather than endogenous institutional arrangements. This raises a sharp question: when external funding ends, can the One Health pilot translate into sustainable national capacity?

4. Financing and Resource Barriers: The Trap of Reactive Financing

4.1. The "Outbreak-Driven" Fiscal Logic

Global health financing historically follows a reactive pattern: funds are mobilized after outbreaks, rather than invested in prevention. World Bank and Africa CDC reports note that through integrated One Health cost calculation tools, Africa could save up to $2.4 billion annually in response costs, yet preventive investment remains grossly inadequate. This "outbreak-dependent" fiscal logic directly undermines the long-term, cross-sectoral capacity building required by One Health.

For hantavirus specifically, this means the cyclical collapse of surveillance networks: rodent host monitoring requires continuous fieldwork and laboratory support, yet funding typically evaporates within 1–2 years after an outbreak. Cross-sectoral projects fall into budgetary vacuums—when an intervention simultaneously involves health, agriculture, and environment (e.g., improving grain storage facilities to reduce human-rodent contact), it often cannot be coded into any single ministry's budget line, becoming a "no-man's-land." Furthermore, the community solidarity and religious resilience revealed in Panama's ethnonursing study could serve as foundations for participatory surveillance, yet lack long-term, small-scale, flexible community funding [5].

4.2. The Rigid Boundaries of Sectoral Budgets

Budgets are the materialization of power. In most countries, health, agriculture, and environment budgets are compiled by different ministries, reviewed by different parliamentary committees, and governed by different accounting rules and performance indicators. Unlimit Health's analysis uses rabies control as a paradigmatic case: vaccinating dogs is more cost-effective than waiting for human cases, yet funds typically sit in health ministries while agriculture ministries lack the budgetary authorization and capacity to implement animal immunization.

Hantavirus control faces the same budgetary paradox. Brazilian studies demonstrate that forest [4], cornfield, and sugarcane cover proportions are positively correlated with hantavirus case probability, as is rural worker density as a socioeconomic proxy. Effective prevention therefore requires agricultural departments to alter planting structures, environmental departments to restore ecological buffer zones, and health departments to strengthen clinical surveillance—yet their budget cycles, performance evaluations, and accountability targets differ, preventing joint investment.

4.3. External Dependency and Data Sovereignty

Resource-limited countries' dependence on international aid further complicates One Health implementation. A Disease X preparedness review notes that surveillance data sovereignty has become a politically sensitive issue in LMICs—Indonesia once refused to share H5N1 samples due to vaccine access inequities [6], highlighting the structural tension between pathogen/genomic data sharing and fair benefit returns. In Grenada and other Caribbean states, baseline hantavirus data were established largely through Stanford's external funding. While this dependency fills immediate gaps, it may also delay the construction of indigenous financing mechanisms and data governance systems.

5. Data and Technology Barriers: Surveillance Inequity and the Digital Divide

5.1. Data Silos and the Interoperability Crisis

The ideal state of One Health is "One Data, One Truth, One Action," yet the reality is a highly fragmented data landscape. Human health, animal health, and environmental health data systems are typically managed by different IT platforms using different data standards, coding systems, and privacy regulations, lacking interoperability.

In the hantavirus field, this fragmentation manifests as clinical-ecological data rupture: human clinical and epidemiological data reside in health ministry infectious disease reporting systems, while rodent capture rates, seroprevalence, and habitat characteristics reside in academic institutions or agriculture ministries, with minimal real-time linkage. Climate-health data misalignment is equally severe: the Latin American systematic review showed most studies use global climate databases (e.g., ERA5) rather than local meteorological station data, with spatial resolution insufficient to capture micro-scale rodent-human contact interfaces. Community-based event surveillance (EBS) in hantavirus-endemic areas often remains informal and temporary, lacking institutionalized interfaces with official reporting systems.

5.2. The "90% Inequity" in Genomic Surveillance

Genomic sequencing is the cornerstone of pandemic preparedness, yet its global distribution is profoundly inequitable. In 2021, over 90% of SARS-CoV-2 sequencing sequences originated from high-income countries (HICs), despite many LMICs experiencing severe outbreaks. This "genomic inequity" carries identical warnings for hantavirus and Disease X: regional variations in ANDV and other hantavirus strains may affect diagnostic test sensitivity, yet sequencing capacity in Latin America and the Caribbean is too weak to detect antigenic drift in real time. During outbreaks, the absence of local sequencing capability means samples must be sent abroad, delaying tracing by weeks or months and missing early containment windows. LMICs' concerns that genomic data may be exploited by external institutions for vaccine/drug development without fair benefit-sharing create political resistance to data sharing.

5.3. The Promise and Gap of Digital Tools

While mHealth, artificial intelligence, and satellite remote sensing offer new tools for One Health surveillance, their coverage and applicability in resource-limited settings remain severely uneven. Disease X preparedness reviews note that while real-time digital surveillance tools are promising, coverage is patchy, and political instability plus weak public health infrastructure hinder progress in many regions. In rural Panamanian hantavirus-endemic areas, community health workers lack digital reporting tools; abnormal health events rely on oral transmission, creating a dual bottleneck of "digital divide" and "information delay."

6. Workforce and Capacity Barriers: Disciplinary Silos and "Language Barriers"

6.1. Separated Education Systems and Professional Socialization

One Health demands deep collaboration between medicine, veterinary science, and ecology, yet globally these professional training systems have long been isolated. Medical students rarely receive animal epidemiology training; veterinarians lack clinical public health perspectives; and ecologists often remain peripheral to health policy processes. WOAH reports note that individual and organizational barriers include "limited awareness or understanding of One Health concepts, different professional cultures and languages, and lack of incentives for cross-sectoral participation."

This "language barrier" is not merely metaphorical. Medicine, veterinary medicine, and ecology possess different terminologies, research paradigms, and journal cultures, generating high cross-disciplinary communication costs. An analysis of East African One Health challenges notes that "some sectors (especially veterinary and environmental) contribute weakly to collaboration, data sharing, and strategic coordination with poor integration."

6.2. Absence of Shared Competencies

Effective One Health practice requires a set of "meta-competencies," including systems thinking, cross-sectoral communication, participatory research methods, and cultural humility. Yet existing continuing education and in-service training rarely cover these. Community health workers, veterinarians, and environmental officers typically receive separate training, lacking shared capacities for joint surveillance and response.

In Grenada's One Health pilot, the research team had to build interdisciplinary workflows from scratch: the medical school handled clinical surveillance, the veterinary school animal sampling, and the ecology team habitat assessment, with data integration dependent on Stanford's external coordination. While effective during the pilot phase, this model is difficult to scale—because at the national level, there are insufficient numbers of "bilingual" or "trilingual" professionals fluent in clinical, veterinary, and ecological languages.

6.3. Misaligned Incentive Structures

Academic evaluation and career promotion systems further reinforce disciplinary isolation. Medical students gain no promotion credit from publishing in veterinary journals; veterinarians engaging in ecological research are seen as "neglecting their proper duties." In resource-limited countries, public health personnel face heavy basic medical service burdens with no time for cross-sectoral activities; agriculture and environment department technicians lack formal responsibilities and incentives to participate in disease surveillance.

7. Community and Cultural Barriers: The Exclusion of "Local Knowledge"

7.1. Top-Down Technocratic Models

Many One Health initiatives adopt top-down designs, treating communities as passive intervention objects rather than active knowledge producers and risk perceivers. This technocratic approach neglects the value of indigenous knowledge and ethnoecology, leading to cultural disembedding of interventions. Systematic reviews consistently rank "community engagement gaps" as the foremost barrier to effective surveillance and response. Henley et al. emphasize that frameworks must engage communities—especially rural and marginalized populations—because they are often the most vulnerable and the earliest "social sentinels" perceiving anomalous changes.

7.2. Cultural Beliefs and Prevention Compliance: Lessons from Panama

Garcia et al.'s ethnonursing study in a rural Panamanian hantavirus-endemic community provides the most in-depth evidence to date on cultural barriers. The study found three coexisting belief systems regarding hantavirus transmission:

1. Scientific cognition: Recognition of rodent excreta aerosol transmission;
2. Cultural misconception: Firm belief that agricultural fumigation directly causes hantavirus ("her illness was caused by fumigation");
3. Hybrid explanation: Belief that rodents become "chemically contaminated" by ingesting pesticides and subsequently transmit disease.

Residents holding the latter two beliefs often doubt the effectiveness of rodent control measures, believing that "even if rats are eliminated, hantavirus will still exist," thereby reducing willingness to participate in official prevention programs. This cultural misconception does not stem from ignorance, but from the agricultural sector's long-term promotion of

pesticides without synchronized health sector risk communication—it is essentially the projection of governance fragmentation at the community cognition level.

7.3. Religious Resilience, Social Capital, and the Exposure Paradox

The Panama study also reveals unique community resources for disease coping. Religious beliefs (syncretic Catholicism and local religious practices) provide psychological resilience, while community mutual-aid networks (neighbors visiting and caring for patients) constitute informal social safety nets. However, this social capital also creates an "exposure paradox": intensive social interactions (festivals, religious celebrations, family gatherings) increase aerosol exposure risks in poorly ventilated enclosed spaces. Traditional One Health frameworks tend to treat communities as objects of "risk behavior" correction rather than "coping resource" activation, missing opportunities to transform religious leaders and community elders into health advocates.

7.4. Historical Distrust and Data Reporting

Socio-cultural barriers also include historical distrust. Past mistakes in health crisis management (such as coercive public health measures disrespectful of cultural customs) may create trust deficits between communities and health organizations, hindering collaboration, data sharing, and case reporting. In the hantavirus field, this distrust manifests as skepticism toward "outside experts," passive cooperation with government rodent control actions, and hesitation to participate in clinical trials.

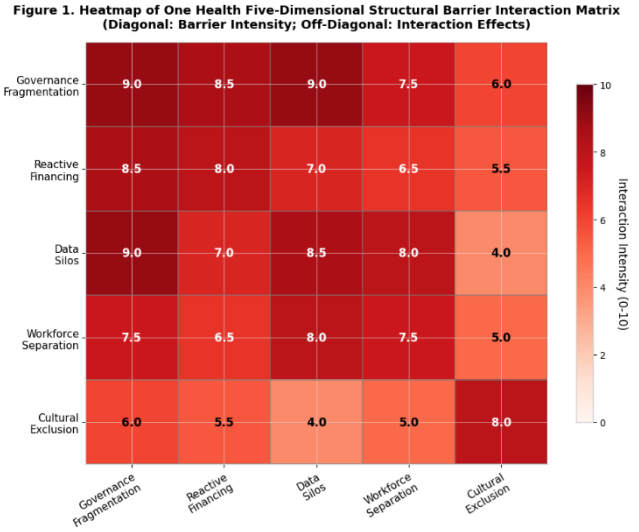
8. Hantavirus as a "Diagnostic Lens": The Syndromic Pattern of Structural Barriers

8.1. Case Integration: Interactive Reinforcement of Barriers

When the five dimensions of barriers are placed within the specific context of hantavirus, they are not independent but reinforce each other through a "barrier matrix" (Figure 1):

Table 1. Interactive Matrix of One Health Structural Barriers in the Hantavirus Context

Barrier Dimension	Hantavirus Context Manifestation	Interaction Effect
Governance Fragmentation	Health-agriculture-environment sectors operate in silos	Climate-ecological data excluded from public health early-warning systems
Reactive Financing	Short-term post-outbreak funding; no sustained host surveillance	Baseline data absent; Grenada relies on external academic grants
Data Silos	Human cases, animal hosts, and climate data stored in separate systems	Delayed outbreak tracing; predictive intervention impossible
Workforce Separation	Clinicians lack rodent ecology knowledge; veterinarians lack public health training	Clinical diagnosis disconnected from ecological intervention
Cultural Exclusion	Panamanian community attributes virus to pesticide fumigation	Low rodent-control compliance; agricultural policy conflicts with health messaging



Diagonal values indicate the independent intensity of each barrier dimension (0–10 scale); off-diagonal values indicate cross-dimensional interaction reinforcement effects. Darker colors represent higher barrier intensity or interaction strength. Data are derived from a composite qualitative assessment of evidence presented in Sections 3–7 of this review.

8.2. From Hantavirus to Disease X: The Amplification Effect of Barriers

The structural barriers observed in hantavirus are not isolated, but represent systemic vulnerabilities in global pandemic preparedness. Disease X—a hypothetical pathogen with pandemic potential—will almost certainly originate at a zoonotic interface, and the fragmented surveillance systems, resource scarcity, and governance weaknesses of LMICs make them ideal environments for viral spillover and cryptic transmission.

Specifically, early detection delays constitute the greatest risk: due to weak community-based surveillance (CBS), insufficient laboratory capacity, and lack of cross-sectoral data integration, Disease X may spread silently for weeks or months in rural LMICs before recognition. The 2014 West Africa Ebola outbreak and early community transmission of COVID-19 in Africa and South Asia both experienced similar recognition delays. When Disease X crosses borders, countries lacking institutionalized coordination platforms cannot rapidly mobilize multi-sectoral resources; IHR (2005) obligations and Joint External Evaluations (JEE) often remain on paper with limited impact on daily operations. Furthermore, with >90% of sequencing capacity concentrated in HICs, variant monitoring and diagnostic kit updates for Disease X will severely lag viral evolution speed, replicating the history of COVID-19 variants going undetected in Africa. Community-level distrust not only reduces prevention compliance but also

provides fertile ground for "infodemics," exacerbating social chaos and political resistance.

8.3. The Cross-Domain Warning of the Cruise Ship Outbreak

The 2026 MV *Hondius* ANDV outbreak condensed One Health structural barriers in an extreme form: confined spaces (environmental engineering), transnational travel networks (transport/tourism sectors), polar special ecology (environmental/scientific research sectors), clinical treatment (health sector), and international legal jurisdiction (maritime/diplomatic sectors) intersected, exposing the governance architecture's dysfunction when confronting "trans-sectoral" risks. This event signals that One Health must connect not only human-animal-environment interfaces, but also local-national-global-supranational (e.g., Antarctic Treaty system) multi-layer governance scales.

9. Pathways Forward: From Aspiration to Institutionalization

9.1. Governance Reconstruction: From "Coordination" to "Integration"

(1) Legal Mandates and Standing Platforms

The Lancet Commission suggests that global One Health governance could draw on models such as the IPCC or IPBES, establishing science-policy interface institutions with legal authority, dedicated personnel, and adequate resources. At the national level, One Health standing coordination bodies should be established through legislation or executive order, empowered with legal authority for cross-sectoral data access, budget integration, and emergency mobilization.

(2) Local Integration Units

At district and community levels, Kenya's proposed "district-level One Health service delivery model" could be adapted, establishing joint working groups comprising local health officers, veterinarians, environmental officers, and community representatives to hold regular cross-sectoral meetings sharing surveillance data and risk assessments.

9.2. Financing Innovation: From "Silos" to "Pooling"

(1) Integrated Budgeting Mechanisms

A "One Health pooled fund" should be established, with contributions from health, agriculture, and environment departments at agreed ratios, financing cross-domain preventive projects. Africa CDC calculations show integrated One Health costing tools could save Africa $2.4 billion annually in response costs. Such funds should prioritize host surveillance, landscape management, and community participation in "no-man's-land" zones.

(2) From Reactive to Anticipatory Financing

The Pandemic Fund, World Bank, and regional development banks should incorporate One Health preventive investment as core lending and grant conditions, breaking the path dependency of "post-outbreak financing."

9.3. Data Integration: From "Islands" to "Ecosystems"

(1) Interoperability and Data Sovereignty

One Health data standards compliant with FAIR principles (Findable, Accessible, Interoperable, Reusable) should be developed, alongside legal frameworks for data sovereignty and fair benefit-sharing, addressing LMIC concerns about "data colonialism."

(2) Community-Embedded Digital Surveillance

Mobile reporting tools (e.g., ODK, KoBoToolbox) should be integrated with community health worker systems to establish "participatory event-based surveillance," enabling community members to report abnormal deaths, animal behavioral changes, and environmental anomalies in real time, filling official surveillance gaps.

(3) Regional Genomic Networks

Drawing on Africa CDC's Pathogen Genomics Initiative (PGI) model, regional genomic sequencing centers should be established in Latin America and the Caribbean, equipped with portable sequencers (e.g., MinION) for local sequencing and real-time data upload, reducing dependence on external laboratories.

9.4. Workforce Transformation: From "Single Discipline" to "Transdisciplinary"

(1) Educational Reform

Shared One Health core curricula should be introduced in medical, veterinary, and ecology schools, covering systems thinking, cross-sectoral communication, participatory research methods, and ethics. Joint degree programs and rotational internships across disciplines should be established.

(2) Competency Certification

Shared One Health competency frameworks and certification systems should be developed, incorporating cross-sectoral collaboration experience into promotion evaluations, breaking the academic hegemony of "single-discipline publication."

9.5. Cultural Embedding: From "Education" to "Dialogue"

(1) Policy Translation of Ethnonursing Insights

Based on the "cultural care decision-making and action model" proposed by the Panama study, health information should be transformed into communication forms aligned with local cultural logic. Regarding fumigation misconceptions, workshops involving community leaders and religious figures could use "protecting the sanctity of land and family" as a narrative framework to explain rodent ecology and virus transmission mechanisms.

(2) Community Ownership

Existing social networks such as churches and community festivals should be transformed into health promotion platforms, allowing community members to participate in surveillance design, data interpretation, and intervention evaluation, enhancing the local legitimacy of knowledge production.

10. Conclusion

Hantavirus is a long-underestimated public health threat, but this study argues for its repositioning as a "diagnostic lens" for One Health structural barriers. Through the transmission trajectories of hantavirus in Latin America, the Caribbean, and global travel networks, we observe five structural barriers encountered in translating One Health from concept to practice:

Governance fragmentation makes cross-sectoral data integration and joint response the exception rather than the norm; reactive financing relegates preventive surveillance to the budgetary margins; data silos and genomic inequity create "surveillance blind spots" in the Global South; workforce separation prevents effective dialogue among clinical, veterinary, and

ecological knowledge; cultural exclusion transforms the most vulnerable communities into the most silent "data black holes."

These barriers explain not only why hantavirus lacks effective integrated prevention after decades of known existence, but also warn that without deep structural change, Disease X preparedness will repeat the same mistakes. The next pandemic will almost certainly originate at a zoonotic interface, will almost certainly first spread cryptically in resource-limited, poorly monitored, governance-fragmented regions, and will almost certainly only be perceived by global society after crossing borders.

From hantavirus to the next pandemic, what is needed is not more policy declarations, but institutionalized power restructuring: granting legal authority to cross-sectoral coordination bodies, establishing integrated budget pools, unlocking data interoperability while safeguarding data sovereignty, cultivating transdisciplinary professionals, and—most critically—transforming communities from intervention objects into knowledge subjects and action partners. The genuine implementation of One Health depends on whether we are willing to challenge the "iron cage" of sectoralization, the fiscal logic of reactivity, the arrogance of technocentrism, and the power inequities in global health governance.

Only when One Health is translated from rhetoric into structure, from pilot into institution, and from external aid dependency into endogenous capacity, can humanity build a truly resilient global health security architecture before the next pandemic arrives.

REFERENCES

[1] Jonsson, C. B., Figueiredo, L. T., & Vapalahti, O. (2010). A global perspective on hantavirus ecology, epidemiology, and disease. Clinical microbiology reviews, 23(2), 412–441. https://doi.org/10.1128/CMR.00062-09

[2] Yopa, D. S., Massom, D. M., Kiki, G. M., Sophie, R. W., Fasine, S., Thiam, O., Zinaba, L., & Ngangue, P. (2023). Barriers and enablers to the implementation of one health strategies in developing countries: a systematic review. Frontiers in public health, 11, 1252428. https://doi.org/10.3389/fpubh.2023.1252428

[3] Mohanty, N., 2025. A Strategic Action Model for Understanding, Designing, and Achieving Community-level One Health Implementation. Medical Research Archives, [online] 13(10). https://doi.org/10.18103/mra.v13i10.7040

[4] Douglas, K. O., Payne, K., Sabino-Santos, G., Jr, & Agard, J. (2021). Influence of Climatic Factors on Human Hantavirus Infections in Latin America and the Caribbean: A Systematic Review. *Pathogens (Basel, Switzerland)*, *11*(1), 15. https://doi.org/10.3390/pathogens11010015

[5] Garcia, J. A., de Isaacs, L. G., Escalante-Barrios, E. L., & Fàbregues, S. (2025). Beliefs and socio-cultural perspectives on hantavirus in a rural community in Panama: An ethnonursing study. *PLOS global public health*, *5*(10), e0005320. https://doi.org/10.1371/journal.pgph.0005320

[6] Kayembe-Mulumba, B., N'gattia, A. K., & Belizaire, M. R. D. (2025). One Health, Many Gaps: Rethinking Epidemic Intelligence in Resource-Limited Settings to Prepare for the Global Threat of Disease X. *Microorganisms*, *13*(11), 2615. https://doi.org/10.3390/microorganisms13112615