

Opinion

Open Access



# Lessons learned from the history of rabies vaccination in Colombia using the one health approach

Natalia Cediel-Becerra<sup>1</sup> , Roseanna Collins<sup>2</sup>, Daniela Restrepo-Botero<sup>3</sup>, María Camila Pardo<sup>4</sup>, Luis Joaquin Polo<sup>5</sup>, Luis Carlos Villamil<sup>6</sup>

<sup>1</sup>Epidemiology and Public Health Group, School of Agricultural Sciences, Universidad de La Salle, Bogotá 111711, Colombia.

<sup>2</sup>UK Health Security Agency, London, SW1P 3JR UK.

<sup>3</sup>School of Agricultural Sciences, Universidad de La Salle, Bogotá 111711, Colombia.

<sup>4</sup>Animal Health Industry Consultant, Athens, GA 30605, USA.

<sup>5</sup>Facultad de Medicina Veterinaria y de Zootecnia, Universidad Nacional de Colombia, Bogotá 110321, Colombia.

<sup>6</sup>Sociedad Colombiana de Historia de la Medicina y de la Academia Nacional de Medicina de Colombia, Bogotá 111711, Colombia.

**Correspondence to:** Prof. Natalia Cediel-Becerra, Epidemiology and Public Health Group, School of Agricultural Sciences, Universidad de La Salle, Cra. 7 # 179-03, Bogotá 111711, Colombia. E-mail: nmcedielb@unisalle.edu.co

**How to cite this article:** Cediel-Becerra N, Collins R, Restrepo-Botero D, Pardo MC, Polo LJ, Villamil LC. Lessons learned from the history of rabies vaccination in Colombia using the one health approach. *One Health Implement Res* 2023;3:42-54. <https://dx.doi.org/10.20517/ohir.2023.01>

**Received:** 1 Jan 2023 **First decision:** 27 Apr 2023 **Revised:** 24 May 2023 **Accepted:** 14 Jun 2023 **Published:** 25 Jun 2023

**Academic Editor:** Charles E. Rupprecht **Copy Editor:** Pei-Yun Wang **Production Editor:** Pei-Yun Wang

## Abstract

Canine and human rabies vaccination in Colombia began at the National Institute of Health in the second decade of the 20th century. The National Veterinary School (the National University of Colombia) also contributed to the vaccination and diagnosis of canines, in addition to the diagnosis of rabies in wildlife. A combination of international cooperation and, from the 1960s onwards, increased funding of several national institutions to support the production of animal vaccines served to further progress rabies research, vaccination campaigns and diagnosis in Colombia. The country's success in controlling canine-transmitted rabies, resulting in an approximately 90% reduction in national human rabies cases, was recognised throughout the Americas; consequently, the activities were modelled in other nations of the region. Additionally, the Ministry of Health played a key role in controlling bovine outbreaks to minimise infection risk in animal carcasses for human consumption in northern Colombia. However, in 2000, the public laboratories for vaccine production for humans and animals were closed, creating a gap in cost-effective disease control strategies in the country. In reviewing the



© The Author(s) 2023. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, sharing, adaptation, distribution and reproduction in any medium or format, for any purpose, even commercially, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.



history of rabies control in Colombia through a One Health approach, we present some lessons learned and propose improvements for the country's long-term rabies vaccination programmes through the integration of human and animal (both domestic and wild) activities in vaccine production and roll-out. Furthermore, we highlight the importance of engaging various government, academic, private, non-government agencies and general public stakeholders in rabies control and prevention programs, especially those in remote rural settings. Finally, we present a proposal to create the national One Health Strategic Action Plan to support the operationalization of a cross-sectoral integrated zoonoses control programme in Colombia.

**Keywords:** Rabies, one health, vaccination, cats, rural, Colombia

## INTRODUCTION

Historically, Colombia has been recognized for its leadership in the control of canine rabies in the Americas region due to its extensive and inclusive vaccination campaigns<sup>[1]</sup>. However, the decentralization of public health services in the 90's generated key challenges, including access barriers, weak governance, and the involvement of multiple actors with scarce coordination and lack of an integrated information system<sup>[2]</sup>. The rabies national control program in Colombia was also hindered by the fragmentation and specialization across sectors, resulting in two separate national programmes: one focused on animal health in the countryside, the other orientated around human health in large, populated areas. However, since 2008, increasing evidence demonstrates cats, not dogs as is usual, are primarily responsible for human infection with rabies in Colombia and, crucially, transmit wildlife variants of the virus<sup>[3]</sup>. The role of cats as focal, non-reservoir vectors of wild rabies variants in the nation demonstrates the need for a combined approach for long-term prevention planning under a One Health approach. Published by the One Health High-Level Expert Panel (OHHLEP) in 2022, the new definition of One Health aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. It promotes cross-disciplinary, multisectoral collaboration at varying levels of society, including communities, to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for healthy food, water, energy, and air, taking action on climate change and contributing to sustainable development. The framework proposes basic principles to guide action: equity, inclusivity, equal access, parity, socio-ecological equilibrium, stewardship and transdisciplinarity<sup>[4]</sup>.

With human cases resulting from animal (both wild and domesticated) interactions, which are in turn underpinned by sociopolitical and environmental dynamics, rabies is, at its core, a One Health issue. Employing this approach, we evaluated the history of rabies vaccination in Colombia to understand the strengths and weaknesses of the National Program to guide future interventions. The success of the canine vaccination campaigns conducted throughout the nation in the 1960s can be used as a model for future efforts, orientated around stakeholder cooperation at the human-animal-environment interface and employing vaccination programmes focused on the four C's (4Cs): communication, coordination, collaboration, and capacity building. Such principles are critical to expand the national rabies control programme to enable the integration of domestic feline and wildlife vaccination and surveillance.

## THE CHRONICLES OF VACCINATION FOR RABIES CONTROL IN COLOMBIA

### Pre- and post-Spanish Colonisation (second half of the 18th century)

Rabies virus transmitted by vampire bats was likely already present in the New World, well before the Spanish arrival during 1492. However, the intensification of cattle farming by the Spaniards opened an ecological niche. In providing a constant food supply, bat populations boomed which promoted the onward transmission of the virus into domestic populations, particularly cattle. Similarly, having been absent among

domestic dogs of the Native Americans, the importation of many new breeds promoted spill-over events into canines, commencing their role as the primary reservoir of rabies during this time<sup>[5-7]</sup>.

### **Beginning of the 20th century**

In 1917, an important initiative was established in Colombia, commencing research on canine and human rabies, and human rabies vaccination at the Colombian National Institute of Health. Research, diagnosis and vaccination campaign efforts were supported through international collaboration with organizations from Europe (Boehringer Private Laboratory, Germany, and Zooprohylactic Institute in Brescia, Italy) and, most notably, the United States (Rockefeller Foundation, Kellogg's Foundation, Ford Foundation, Cornell University, Illinois University, Nebraska University, University of Texas)<sup>[8,9]</sup>. The rapid advancements seen at the beginning of the rabies prevention program in Colombia were attained as a result of this support and the unified vision of international academic partners.

Throughout this time period, the field of vaccine production in the country underwent significant changes. Initial production, established in 1942, was conducted in lamb brains; in 1944, production changed to the use of calf brains with inactivation via phenol and heat. In 1954, Eduardo Fuenzalida and Raúl Palacios developed a vaccine in suckling mouse brains. This vaccine was first licensed for use in humans in Chile in 1960, and later adopted by Uruguay for human PEP in 1963, followed by Argentina and Peru in 1964, Brazil and Venezuela in 1965, Cuba and Mexico in 1967, and Ecuador and Guatemala in 1969<sup>[9]</sup>. However, the nervous tissue of the mice resulted in serious side effects in some recipients; between 1967 and 1973, there were 21 cases of neuroparalytic reactions in humans who received the post-exposure rabies vaccination, the vast majority of whom were infected by dogs<sup>[8]</sup>. These individuals had received between 4 and 18 doses of the vaccine, and 11 of the adverse reactions resulted in fatality. Consequently, the routine number of post-exposure doses was reduced from 21 to 14, and subsequently again to 7, after which a reduction in the number of such adverse reactions was observed. Additional complications included the difficulty in maintaining the cold chain throughout the vaccine lifecycle<sup>[9]</sup>.

### **1955 to 1970**

Several institutions were funded to support rabies animal vaccine production. The Colombian Agricultural Institute (ICA) conducted animal rabies diagnosis and the Colombian Vaccine Production (VECOL) supported animal rabies vaccine production<sup>[10]</sup>. Notably, the first institutional bat rabies campaigns conducted in La Guajira, northern Colombia, in the 1960s are an excellent example of the utilization of the 4Cs under a One Health approach. Sponsored by the health sector, the Ministry of Health trained agricultural veterinarians to recognize and control outbreak rabies aiming to reduce onward transmission and control outbreaks in bovines intended for human consumption as the carcasses were posing a substantial human health risk<sup>[11]</sup>. Despite that, at that time, One Health was not yet recognized as a framework, the activities of the Colombian government in this decade exemplify coordination for capacity building for infectious disease control.

Another demonstration of coordinated actions among stakeholders is the integrated effort demonstrated by the Colombian leadership on canine rabies vaccination campaigns. Successfully reducing dog-transmitted rabies in humans by 90% in the 1960s, the efforts in Colombia were modelled by the Pan American Health Organization (PAHO) across Latin America in line with the blueprint for the "Rabies Control and Prevention Roadmap"<sup>[1,9]</sup>. This was achieved by ensuring 70% vaccine coverage in canines, encouraging laboratory-based surveillance, and enhancing rabies virus diagnosis and genotyping in domestic animals, including dogs and wildlife. These activities were supported by the continual targeting of health education campaigns among the most at-risk populations regarding transmission, prevention, and responsible pet ownership<sup>[9,11]</sup>.

An example of such efforts are those conducted in the city of Cali. Throughout 1965, local governments received large numbers of complaints regarding bites from stray, unknown and suspected-rabid dogs, as well as information requests from neighbors of rabies cases. Rates of rabies-associated deaths were high - over 40 per annum - and the majority of those infected were children. Consequently, epidemiological investigation was established. Beginning in neighborhoods, search teams of local volunteers (school teachers, communal action boards, health center officials, priests, and municipal authorities) went house to house to look for individuals who had been bitten. These activities generated the development of a strategy which was expanded to all other departments nation-wide with the aim of reducing canine-borne rabies and human deaths. Efforts were intensified during 1969 when preparatory meetings for the planning of the 1971 Pan American Games, due to be hosted in Cali, were initiated. In identifying safety strategies for the Olympic village, a member of the International Olympic Committee raised concerns regarding the risk of rabies to athletes and visitors, as a threshold of zero cases was required. Consequently, the “Cali Free of Canine Rabies” campaign was established with the slogan: “a commitment from Cali, vaccinating 100,000 dogs against rabies”<sup>[1]</sup>.

The successful dog rabies campaigns were based on key principles, particularly the engagement of multiple stakeholders, strongly interrelated with the One Health approach [Figure 1]. These experiences demonstrating community engagement and commitment, both by the public and private sector, are crucial strategic elements in ensuring the effectiveness of interventions<sup>[9]</sup>.

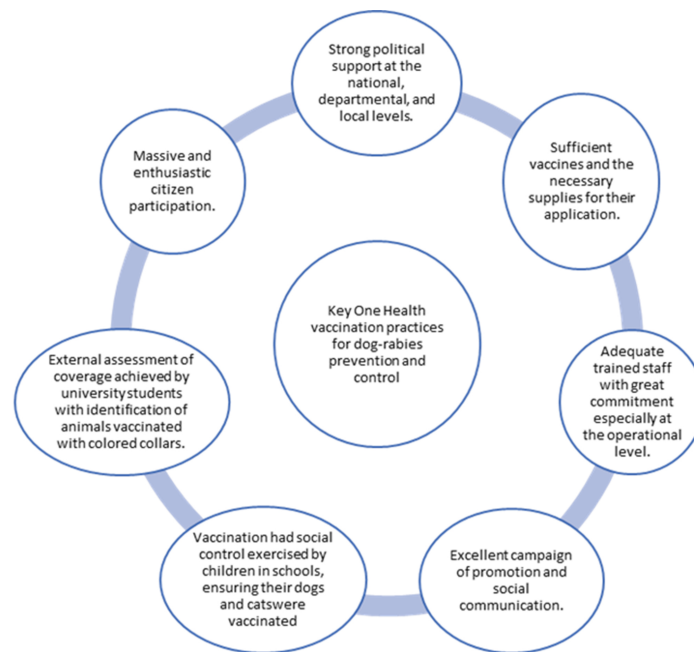
### 1970s and 1980s

By 1979, the laboratory where rabies vaccines were produced was renamed as the National Institute of Health. There, among other vaccination types, 841,800 doses of canine rabies vaccine and 320,348 doses of human rabies vaccine were produced annually. The national population was not the only beneficiary - twenty countries in Central America, South America, the Caribbean, and Africa imported biological products against rabies produced in Colombia<sup>[12]</sup>. Similarly, the Vecol laboratory of the Colombian Veterinary Products Company, under the advisory of the Pasteur Institute, produced rabies vaccines for veterinary use<sup>[11]</sup>. Consequently, in 1988, PAHO-WHO, the Rockefeller Foundation and the U.S. Centre for Disease Control selected Vecol to lead the establishment of a pilot production plant. Here, they manufactured rabies vaccines for both human and animal use using Vero cells (taken from the kidney of African green monkeys), replacing the aforementioned suckling mouse brain tissue which resulted in adverse reactions<sup>[13]</sup>. The first three batches produced were tested at the Agriculture and Livestock Colombian Institute (ICA) and the Pasteur Institute with promising results<sup>[10]</sup>.

The national programme for the control of rabies in bats began in the early 1980's when the first reports of human cases resulting from bat transmission were recorded in the Darien Gap. With support from PAHO/WHO, leading experts in vampire bat rabies were deployed from Mexico to tackle the spread of the virus and train Colombian personnel. Their equipment included: nets for capture of the bats; moon calendars; Vampirimid (Mexican brand of Warfarin, a product used to cull bat populations); lamps; ropes; and bovine rabies vaccines for reduction of onwards human transmission via consumption. The success of this programme resulted in its replication in other regions across Colombia where vampire bat rabies predominated including La Guajira, Cesar, Llanos Orientales (Eastern Plains), Urabá antioqueño, Córdoba, Sucre, among others<sup>[11]</sup>.

### Between 1994 and 2000

Decentralization of public health services in Colombia was supported by Law 10 of 1990 and Law 100 of 1993, serving to fragment the national control of rabies and other infectious diseases in several departments of the country<sup>[2]</sup>. It resulted in activities such as animal vaccination, surveillance and animal population



**Figure 1.** Key One Health components of the “Cali Free of Canine Rabies” campaign in Colombia, 1969.

control programs for the urban cycle of disease, being unequally performed around the country, particularly neglecting remote, rural locations. This fragmentation also affected the National Institute of Health (INS). Between 1994 and 2000, the laboratories for the production of vaccines and serums were closed, including those for human and canine rabies which had produced batches of 80 thousand doses per month. This was due to the limited budget to sustain their operation. The facilities required a multi-million dollar investment to adapt them to the international standards of PAHO, and it was cheaper to import vaccines or to purchase the products from private laboratories. The Vecol laboratory also ceased production of human vaccines as of 2003, subsequently only providing vaccines for veterinary use<sup>[1]</sup>. Consequently, Colombia went from exporting biologics to different countries around the world to importing vaccines and suffering shortages, particularly in outbreak situations. Despite this, throughout 1997, various outbreaks were controlled across Latin America through the establishment of mass canine prophylaxis campaigns. As a result, genetic variant 1 is now extremely rare; genetic variant 2, however, continues to circulate in Magdalena, the Caribbean, and accounts for the majority of cases in Colombia to this day. This presents a significant ecosystem health threat, as explored within the subsequent section, this region in Colombia continues to present a foci location for the transmission of rabies variant 2 in foxes<sup>[14]</sup>.

### 2000 until present day

The rabies activities over the recent two decades paint a complex picture.

#### *Domestic animals and livestock*

With respect to domestic animals, the Colombian government prioritized dog rabies vaccination in hotspots, thus creating a heterogeneous profile of vaccine coverage across the country<sup>[15]</sup>. As such, despite average immunization coverage increasing from 45% in 1994 to 63% in 2005 and no canine-associated rabies fatalities in humans since 2007, only a quarter of all Colombian departments have a coverage greater than 60% - and these are likely overestimates<sup>[15]</sup>. Rabies vaccination coverage in Bogota was found to be just 43% in 2011, one of the lowest in the last twenty years and vastly under the WHO-recommended coverage of 70% for outbreak prevention<sup>[16,17]</sup>. The same study demonstrated that some areas of the city had low

accessibility to canine and feline vaccinations for pet owners<sup>[16]</sup>. If an urban, affluent area like Bogota has low access and coverage, then it is likely access to rabid vaccination in rural areas is even lower. Moreover, recent studies show that many vaccinated animals do not reach the threshold level of immunity in accordance with the anti-rabies antibody titre as defined by the World Health Organization of Animal Health (WOHA, formerly OIE)<sup>[18,19]</sup>. This highlights logistical failures in cold chain maintenance and expiration dates in supply chains, often due to the complicated climatic, geographical and social conditions of some regions<sup>[20]</sup>. However, the Colombian Ministry of Health must be commended on their targeting of pets in areas which border Venezuela (La Guajira, Cesar, Norte de Santander, Arauca, Vichada, and Guainia) where rabies is still a major public health concern in many areas - a necessary step to prevent overflow across the frontier<sup>[21]</sup>. The status of rabies in Colombian livestock, however, is a much bleaker picture. The presence of rabies disease in cattle was reported in 62.5% of the country's departments and livestock vaccination coverage was found to be less than 10% in the susceptible cattle population - however, this data is from 2014 and vaccination coverage has improved substantially since anti-rabies vaccination campaigns are done together with foot-and-mouth disease campaigns in the country<sup>[22]</sup>. In 2023, the Agriculture and Livestock Colombian Institute (ICA), launched the Resolution 4003, which established the period and conditions of the first cycle of vaccination against foot-and-mouth disease, bovine brucellosis and rabies by the year 2023 in the national territory. In this coming cycle, ICA will vaccinate 10 million animals located in 18 departments, a historic number for the country. In this regard, evidence shows a decrease in bovine cases over 14 years from 2005 onwards, with a maximum of 542 in 2014 and a minimum of 43 in 2019. The greatest cluster occurred in the Orinoquia region, and the departments of Antioquia, Arauca, Casanare, Cesar, Magdalena and Córdoba continually report the highest number of bovine rabies cases<sup>[23]</sup>.

### *Wildlife*

Additionally, in the early 2000s, evidence was found of circulation of the rabies genetic variant 2 among Colombian wildlife. Notably, a number of grey foxes (*Urocyon cinereoargenteus*) in northern Colombia have been found to have been infected with rabies, likely transmitted from domestic canines<sup>[14]</sup>. This presents a major public health threat in the region as these foxes frequently interact with farmers, pets, and livestock, providing an optimal scenario for the sustenance of rabies transmission between wildlife and domestic animals, and subsequent overflow into humans. Evidence generated by the local department of Magdalena presented the major enabling factors, most notably overlapping niches and phylogenetic proximity between the two species<sup>[14]</sup>. This demonstrates the need to employ a One Health approach to expand surveillance into local wildlife populations, ensuring to address all elements of the human-animal-environment interface where rabies predominates. With respect to vampire bat rabies - as aforementioned, the key for human infection in Colombia - historical efforts focused on culling have proven disruptive to ecosystems and ineffective, often exacerbating rabies spread as populations disperse. A major determinant of an intervention's success is its acceptability among target communities; however, attitudes towards rabies control methods are heterogenous. The general public typically view population control as inhumane, whereas farmers welcome more intensive methods, such as culling, due to fear of poor livestock health and profit loss. Consequently, recent research is oriented around the development of preventative methods such as oral vaccination, which shows promise in reducing onward transmission without promoting survival of rabies-infected bats, which appeals to farmers. As of yet, however, their immediate deployment for control is not feasible<sup>[24]</sup>.

### *Humans*

In Colombia, risk of human rabies transmission and infection is highest among populations which live in close contact with animals, such as indigenous persons and cattle farming communities, and have nearby occurrences of rabies in wildlife, particularly where the primary reservoir is the vampire bat, *Desmodus*

rotundus. Attempts by the government to establish milk and meat production in the jungles of the Amazon and Orinoquía opened new ecological niches for some wild species, including bats and carnivorous animals, resulting in them changing their diets to feed on domestic animals. However, transhumance is the primary mode of farming in this region, wherein herds are continuously moved to more productive regions. When this occurs, the bats lose their primary food source, causing them to redirect their feeding again, this time to local indigenous communities, predominantly children. This is evidenced by the increase in notifications of exposures (bites) in departments such as Vaupés, Amazonas, Guaviare, Meta, and Caquetá. For example, the Emberá community (Bajo Baudó, Chocó) suffered an outbreak in 2004 which resulted in 17 fatalities, the majority of which were in children<sup>[25]</sup>.

## THE SOCIOPOLITICAL LANDSCAPE OF RABIES IN COLOMBIA

Under a One Health approach, it is crucial to examine all working parts of the human-animal-environment triad. The three elements are heavily underpinned by sociopolitical context and, thus, so is rabies transmission, prevention and control. Consequently, understanding the interplay of social, cultural, political and economic factors is vital for the implementation of context-specific interventions which are evidence-based, accepted by local communities, and, ultimately, effective.

### Conflict, displacement and poverty

For decades, on-and-off fighting has occurred between different political factions in Colombia. The most recent, an uprising by the Revolutionary Armed Forces of Colombia (FARC) against the government, ended with a peace agreement in 2016, although pockets of fighting remain, particularly in rural areas of the country where FARC predominated<sup>[26]</sup>. In addition to direct implications on the welfare of the Colombian people, the economy and local drug trade, the conflict indirectly promotes the spread of rabies among human and animal populations. Decades of warfare has resulted in 35.7% of the population living below the National Poverty Line, the majority of whom live in rural areas<sup>[27]</sup>. Areas of lower socioeconomic status are more likely to be inhabited by internally-displaced persons, international refugees and marginalized populations, including those of Afro-Caribbean and indigenous descent - all of whom are more likely to have negative health outcomes as a result, including with respect to infectious disease status such as rabies<sup>[28,29]</sup>. Poverty has a strong, positive correlation with canine rabies. This is likely, in part, due to the association between poverty and poorer healthcare and transport infrastructure, which in turn obstructs rapid diagnosis and treatment in humans and animals<sup>[30]</sup>. Socioeconomic status, underpinned by warfare, also determines a nation's ability to manufacture/procure and deliver vaccinations; thus, Colombia's political instability likely hindered the delivery of presentation vaccinations to animals and post-exposure prophylaxis to humans<sup>[31]</sup>. Areas prone to violence, such as the Department of Chocó, also have disrupted surveillance, in part due to the shift in public priorities as their health is more immediately threatened by warfare<sup>[30]</sup>. The ELN (National Liberation Army) is another armed group that, currently in 2023, is hindering not only vaccination campaigns but also surveillance activities and other health interventions in a large part of the department. Other departments such as Arauca and Caquetá, known as excellent livestock producers, are experiencing the same situation as Chocó. Arauca, dominated by ELN, and Caquetá and Meta, are places that have been forgotten by public health priorities as technical assistance and vaccination campaigns are scarce.

### Indigenous populations

Land-grabbing and deforestation have increased in recent years within Colombia, particularly in the Andes-Amazon regions where wildlife biodiversity is high, including among species of rabies vectors<sup>[32]</sup>. Habitat disturbance positively associated with the presence of rabies in reservoir host and vector species of bats in French Guiana - another Latin American country with parallels to Colombia<sup>[33]</sup>. Consequently, similar anthropogenic activities in rural regions of Colombia likely promote circulation of rabies among local

wildlife populations - a strong risk factor for infection in livestock, domesticated animals and humans. As indigenous people make up 60% of the population in the Amazonian region, interventions must be designed which are orientated around these target populations<sup>[34]</sup>.

Due to their close contact with wildlife, indigenous communities require targeted interventions which respect both their culture and attitudes towards the health-disease interface. This is evidenced through epidemiological data collected over a 10-year period across Colombia, which showed persons of indigenous and Afro-Caribbean descent had the highest exposure to human rabies<sup>[34]</sup>. As such, rabies prevention and control activities must be designed and implemented in collaboration with community leaders and traditional healers to address the One Health principles of sociopolitical and multicultural parity, and transdisciplinarity between epidemiology and indigenous healing practices<sup>[35,4]</sup>.

Establishing preventive programmes in these indigenous communities is complicated. In addition to cultural barriers, including languages and healthcare practices, they live in remote areas which often can only be accessed via rivers, thus, rapid communication to provide timely care is difficult. There is also no electricity making it difficult to maintain the cold chain necessary to preserve the bio-activity of biologicals, particularly with lengthy, short-interval dosing schedules, among other logistical difficulties in the delivery of post-exposure vaccinations. In response to this, shortened schedules have been introduced, including the use of double-dosing on days 0 and 7 post-exposure, with an additional application of anti-rabies serum on day 0 for severe cases. This national post-exposure prophylaxis program, oriented to indigenous and remote communities, was the work presented by the Colombian winner of the George Baer award at the RITA Conference in 2018 in Buenos Aires, Argentina together with the Pan American Health Organization (A. Castro, personal communication, 4th June, 2023).

Although some international authors have assessed the efficacy of bat culling<sup>[36]</sup>, demonstrating that it has minimal effects on rabies seroprevalence when spatially coordinated control is absent, this method is still used at a national level. Besides culling to control wildlife rabies, alternative methods include the use of topical rabies vaccines for wild bats and the use of baits to orally vaccinate fox populations where sylvatic rabies transmission predominates. However, among indigenous populations and the general public, vaccination may be ill-received as they conflict with values of living harmoniously with nature. As such, transdisciplinary communication between key national and international stakeholders, including representatives of indigenous communities, regarding the potential vaccination with recombinant rabies vaccine for vampire bats should be done to explore their potential as a control strategy for RABV in the complex socio-ecological context of Colombia. Despite the difficulties surrounding logistics and provisions of resources, addressing rabies among these regions is critical to promote improved outcomes among these communities and reduce health inequities under a One Health approach. Whilst this requires continuous funding, the direct and indirect costs of non-vaccination on morbidity and mortality in livestock, domesticated pets and humans far exceeds the necessary financial investment. Control of rabies in Colombia is possible, evidenced by the absence of reported human cases of dog-transmitted rabies in urban areas for the last 15 years. However, to expand these results to the neglected rural and indigenous communities requires concerted, non-competitive, collaborative working relations across all sectors responsible for surveillance in the human and animal health components.

### **A need for a renewed chapter of rabies program in Colombia**

The Quadripartite Organizations - the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), the WOAH and the WHO - collaborate to drive the system transformation across all levels (national, regional, and global) required to mitigate the impact of



current and future health challenges at the human-animal-environment interface. In response to this challenge, they drafted the One Health Joint Plan of Action (OH JPA), 2022-2026, which describes their collective commitment to advocate for and support One Health initiatives in accordance with six action tracks. The prevention and control of rabies is categorized under action track 3 which aims to “control and eliminate endemic zoonotic, neglected tropical and vector-borne diseases”. The necessary interventions to achieve this objective, as outlined in the OH JPA, are as follows: implementation of community-centric, risk-based solutions; strengthening of policy and legal frameworks across different levels and sectors; and increase political commitment and economic investment in rabies prevention and control programmes<sup>[37,38]</sup>. Such activities are in-line with the Rabies Blueprint and the Rabies Roadmap; developed by experts in the field, these documents provide nations with actionable, step-wise guidance and measurable objectives in the quest to eliminate dog and fox-mediated rabies under a One Health approach<sup>[39,40]</sup>.

The Colombian political commitment towards the rabies surveillance, prevention and control program has been crucial for its success. The last rabies integrated surveillance protocol launched in 2022 is a proven testimony that official entities are willing to support the integrated activities among sectors<sup>[41]</sup>. In the author’s opinion, mainstreaming One Health principles, especially those associated with equity, inclusion and access, should be taken as priority to evaluate Colombia’s historical vaccination actions in tackling rabies and to plan the future for the national zoonoses control program. Our findings indicate that the greatest success has been demonstrated when Ministries have promoted cross-disciplinary cooperation, bringing together a range of relevant stakeholders to implement system-wide activities. Consequently, we encourage and urge the immediate adoption of a One Health approach within already existing intersectoral mechanisms, such as the National Zoonoses Council, and already existing health policies. Having identified heterogeneity of vaccination coverage among domestic felines and canines, a primary focus of the National Rabies Colombian Program (NRCP) should be to promote the expansion and intensification of vaccination campaigns, particularly among rural populations of these animals, combined with targeted health promotion campaigns directed at rural populations. Importantly, interventions should also be designed to address the economic, social and cultural disparities between rural and urban populations to reduce the neglect of remote communities, particularly indigenous populations, that threatens the success of universal rabies control in Colombia. Additionally, surveillance among domestic animal populations (including cattle) should be integrated with that of wildlife populations, particularly bats and foxes. In addition to being more cost-effective, such an approach will address the primary vectors of human rabies infection, evidenced by the fact that all human rabies cases have occurred by either unvaccinated cats infected with bat rabies or direct contact with vampire bats since 2008. With respect to the human element of the One Health triad, the fragmentation of prevention programmes resulting from changes in national health law was identified as a major factor in their declining success in recent decades. To overcome this, transdisciplinary methods of working must be introduced to promote integrated actions and monitoring between stakeholders, with a particular emphasis on the inclusion of indigenous and other marginalized voices. This requires strong political willpower to ensure funding, good governance, coordination, and leadership. However, bureaucracy, administrative challenges and regular changes in government leadership present major obstacles to this. Moreover, the decline in funding for healthcare, including infectious disease interventions, and fragmentation of the health sector in recent decades demonstrates declining political commitment which, as evidenced, has had detrimental implications on rabies control activities in Colombia. Consequently, strong community engagement with the general public, combined with collaboration from international agencies and non-government organizations (such as the Red Cross, UNICEF, doctors without borders, etc.), must be promoted to lobby political commitment. This will, in turn, enable formalization of agreements irrespective of governance changes and ensure sustainable, impactful engagement from the public political sector which puts One Health at the centre of its principles. Rabies, like all infectious diseases, does not respect borders. As such, concerted efforts must be made for

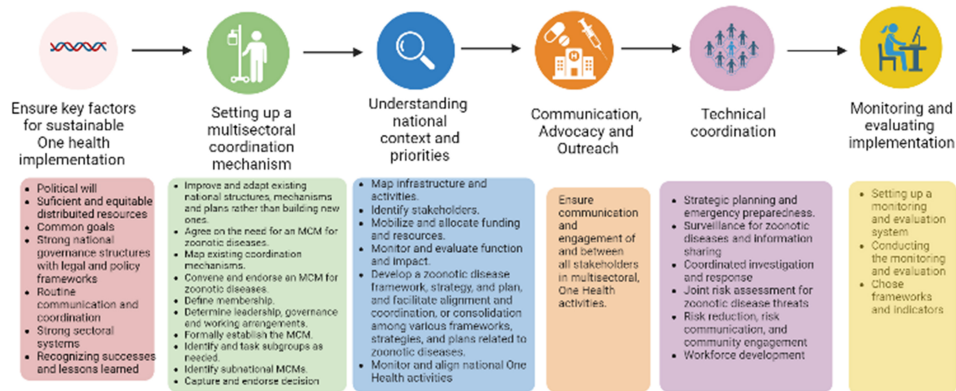
international collaboration across regions. In addition to promoting the sharing of open-access surveillance data in accordance with the Rabies Blueprint, such cooperative agreements help promote political buy-in, transparent working and accountability.

Building on Colombia's history as a leader in the fight against rabies, this model will serve to ensure community-orientated, multidisciplinary action and shared responsibility to reduce the burden rabies poses on human and animal health throughout the nation and the region of Latin America. Colombia was the first country of the Latin America Region to develop a One Health Zoonotic Disease Prioritization (OHZDP) workshop using a multisectoral, One Health approach developed by Centre for Disease Control (CDC), with equal input from representatives of human, animal (livestock and wildlife), environmental health (ecosystem and wildlife), and other relevant partners<sup>[41]</sup>. The specific goals were to use a multisectoral, One Health approach to: (i) prioritize zoonotic diseases of greatest One Health concern; and (ii) develop next steps and action plans to address the priority zoonotic diseases in collaboration with One Health sectors and partners in Colombia. Unsurprisingly, the priority zoonotic diseases for multisectoral, One Health collaboration for Colombia were<sup>[42]</sup>:

1. Avian Influenza
2. Brucellosis
3. Leptospirosis
4. Equine Viral Encephalitis (Western Equine Encephalitis, Venezuelan Equine Encephalitis, West Nile Encephalitis, and Eastern Equine Encephalitis)
5. Zoonotic Tuberculosis
6. Rabies

The next step to strengthen the Colombian zoonoses control program within the global One Health framework is to create and implement the Colombian One Health Strategic Action Plan which would also addresses the social determinants of health including political environment, cultural norms, values, attitudes and beliefs, the economy, the distribution of power, gender and the rural-urban divide. These factors strongly influence zoonotic disease risk thus, must be considered to implement a truly One Health approach within the country. As illustrated in the following [Figure 2](#), One Health tools, such as the Tripartite Zoonoses Guide, support the operationalization of a cross-sectoral national One Health Strategic Action Plan for an integrated zoonoses control programme, tackling rabies and other threats to human, animal and environmental health in Colombia<sup>[43]</sup>. Regarding this initiative, the Academic sector is supporting the implementation activities towards a more holistic rabies prevention and control.

## Proposal for operational guidance for implementation One health in Colombia based on the TGZ



**Figure 2.** Flowchart illustrating actions to implement a One Health approach for the zoonoses control program in Colombia, based on the Tripartite Guide for addressing zoonotic diseases in countries <sup>[43]</sup>.

## DECLARATIONS

### Acknowledgments

We would like to thank to the dedicated and committed work on rabies of many Colombian professionals: Dr. Gabriel Toro, Dr. Cecilia Saad, Dr. Rafael Villalobos, Dr. Arturo Díaz, Dr. Jairo Hernandez, Dr. Angela Xiomara Castro, Dr. Luis Alberto Carreño, Dr. Carlos Rivera, Dr. Juan Carlos Ospina, Dr. Miguel Andrés Paez, Dr. Ricardo León VEGA (RIP,) and Dr. Andrés Osejo, Dr. Fabiola Rodriguez, Dr. Edilberto Brito, Dr. Diego Soler-Tovar.

### Authors' contributions

Made substantial contributions to conception and design of the study and performed data analysis and interpretation: Cediel-Becerra N, Collins R, Restrepo D, Pardo MC, Polo LJ

Performed data acquisition, as well as provided technical and material support: Pardo MC, Polo LJ, Villamil LC

Translation and professional editing: Collins R

### Availability of data and materials

Not applicable.

### Financial support and sponsorship

None.

### Conflicts of interest

All authors declared that there are no conflicts of interest.

### Ethical approval and consent to participate

Not applicable.

## Consent for publication

Not applicable.

## Copyright

© The Author(s) 2023.

## REFERENCES

1. Villamil Jiménez, L.C. Formulación de políticas agrarias y gestión en instituciones publicas y privadas. *Journal of the University of La Salle* 2017; pp. 229-49. Available from: <https://dialnet.unirioja.es/servlet/articulo?codigo=6636419>. [Last accessed on 16 Jun 2023] (in Spanish).
2. Bernal O, Barbosa S. La nueva reforma a la salud en Colombia: el derecho, el aseguramiento y el sistema de salud. *Salud Pública de México* 2015;57:433-40. Available from: [https://www.scielo.org.mx/scielo.php?script=sci\\_arttext&pid=S0036-36342015000500015](https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0036-36342015000500015). [Last accessed on 16 Jun 2023] (in Spanish).
3. Paez A, Polo L, Heredia D, et al. [An outbreak of human rabies transmitted by a cat in the town of Santander de Quilichao, Colombia, 2008]. *Rev Salud Publica* 2009;11:931-43. Available from: <https://pubmed.ncbi.nlm.nih.gov/20379666/>. [Last accessed on 16 Jun 2023]
4. Adisasmito WB, Almuhairi S, Behraves CB, et al; One Health High-Level Expert Panel (OHHLEP). One health: a new definition for a sustainable and healthy future. *PLoS Pathog* 2022;18:e1010537. DOI PubMed PMC
5. Velasco-Villa A, Mauldin MR, Shi M, et al. The history of rabies in the Western Hemisphere. *Antiviral Res* 2017;146:221-32. DOI PubMed PMC
6. Vos A, Nunan C, Bolles D, et al. The occurrence of rabies in pre-Columbian Central America: an historical search. *Epidemiol Infect* 2011;139:1445-52. DOI PubMed
7. Alzate Echeverri AM. Suciedad y orden: reformas sanitarias borbónicas en la Nueva Granada 1760-1810. Textos de Ciencias humanas, Editorial Universidad del Rosario. Available from: <https://www.jstor.org/stable/j.ctt1ggjmh0>. [Last accessed on 16 Jun 2023] (in Spanish).
8. Villamil Jiménez LC. Salud Pública Veterinaria, Retos y Perspectivas. Apuntes de una Vida: Elmer Escobar Cifuentes. Journal of the University of La Salle. Available from: <https://ciencia.lasalle.edu.co/cgi/viewcontent.cgi?article=1451&context=ruls>. [Last accessed on 16 Jun 2023] (in Spanish).
9. Velasco-Villa A, Escobar LE, Sanchez A, et al. Successful strategies implemented towards the elimination of canine rabies in the Western Hemisphere. *Antiviral Res* 2017;143:1-12. DOI PubMed PMC
10. Toro G, Vergara I, Román G. Neuroparalytic accidents of antirabies vaccination with suckling mouse brain vaccine. Clinical and pathologic study of 21 cases. *Arch Neurol* 1977;34:694-700. DOI PubMed
11. Cifuentes E. La rabia, crónica de una experiencia. *Revista Medicina* 2005;27:249-55. Available from: <https://revistamedicina.net/index.php/Medicina/article/view/71-3>. [Last accessed on 16 Jun 2023] (in Spanish)
12. Ibáñez Pinilla EA. Vigilantes de la salud. *Rev Sal Bosq* 2019. Available from: [https://www.researchgate.net/publication/335007151\\_Vigilantes\\_de\\_la\\_salud](https://www.researchgate.net/publication/335007151_Vigilantes_de_la_salud). [Last accessed on 16 Jun 2023] (in Spanish).
13. Halstead SB. Tissue culture-based rabies vaccines: vaccine production technology transfer. *Rev Infect Dis* 1988;10 Suppl 4:S764-5. DOI PubMed
14. Páez A, Saad C, Núñez C, Bóshell J. Molecular epidemiology of rabies in northern Colombia 1994-2003. Evidence for human and fox rabies associated with dogs. *Epidemiol Infect* 2005;133:529-36. DOI PubMed PMC
15. Cediel N, de la Hoz F, Villamil LC, Romero J, Díaz A. [The epidemiology of canine rabies in Colombia]. *Rev Salud Publica* 2010;12:368-79. PubMed
16. Monsalve S, Rucínque S, Polo L, Polo G. [Assessment of the spatial accessibility to the rabies vaccination campaign in Bogotá, Colombia]. *Biomedica* 2016;36:447-53. DOI PubMed
17. Coleman PG, Dye C. Immunization coverage required to prevent outbreaks of dog rabies. *Vaccine* 1996;14:185-6. DOI PubMed
18. Sánchez Bonilla MDP, Gutiérrez Murillo NP, Díaz Sánchez OA, et al. Estado de inmunidad humoral posvacunal de caninos y felinos en un foco de rabia canina de origen silvestre de una región de Colombia. *Rev investig vet Perú* 2020;31:e17822. DOI
19. Páez A, Hernández C, Escobar H, Zapata JJ, Méndez J, Rey-Benito G. [Evaluation of the seroconversion as a response to rabies vaccination in dogs, Valle del Cauca, Colombia, 2009]. *Biomedica* 2011;31:474-84. PubMed
20. Trujillo L, Martínez-Gutierrez M, Ruiz-Saenz J. Low level of the immune response against rabies virus in dogs and cats, a cross-sectional study in sheltered animals, Santander, Colombia. *Pesq Vet Bras* 2018;38:2109-16. DOI
21. Ministry of Health (2020). Ministry of Health Promotes Vaccination of Dogs and Cats to Prevent Rabies. [online]. Available from: <https://www.minsalud.gov.co/English/Paginas/Ministry-of-Health-Promotes-Vaccination-of-Dogs-and-Cats-to-Prevent-Rabies.aspx>. [Last accessed on 25 Jun 2023].
22. Marín Alvarez LM, Ruíz Sáenz J, Ruíz Buitrago JD. Análisis del programa de prevención y control de rabia de origen silvestre y su papel en el número de focos bovinos en el periodo 2001-2011. *Rev CES Med Zootec* 2014;9:203-17. Available from: [http://www.scielo.org.co/scielo.php?script=sci\\_arttext&pid=S1900-96072014000200006](http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S1900-96072014000200006). [Last accessed on 16 Jun 2023] (in Spanish).
23. Bonilla-Aldana DK, Jimenez-Diaz SD, Barboza JJ, Rodriguez-Morales AJ. Mapping the spatiotemporal distribution of bovine rabies in Colombia, 2005-2019. *Trop Med Infect Dis* 2022;7:406. DOI PubMed PMC

24. Cárdenas-Canales EM, Velasco-Villa A, Ellison JA, Satheshkumar PS, Osorio JE, Rocke TE. A recombinant rabies vaccine that prevents viral shedding in rabid common vampire bats (*Desmodus rotundus*). *PLoS Negl Trop Dis* 2022;16:e0010699. DOI PubMed PMC
25. Valderrama J, García I, Figueroa G, et al. Brotes de rabia humana transmitida por vampiros en los municipios de Bajo y Alto Baudó, departamento del Chocó, Colombia 2004-2005. *biomedica* 2006;26:387-96. DOI
26. Fiandrino S, Cattuto C, Paolotti D, Schifanella R. Combining environmental and socioeconomic data to understand determinants of conflicts in Colombia. *Front Big Data* 2023;6:1107785. DOI PubMed PMC
27. The World Bank (2021). Latin America & the Caribbean. Poverty & Equity Brief. Available from: [https://databankfiles.worldbank.org/public/ddpext\\_download/poverty/987B9C90-CB9F-4D93-AE8C-750588BF00QA/AM2020/Global\\_POVEQ\\_COL.pdf](https://databankfiles.worldbank.org/public/ddpext_download/poverty/987B9C90-CB9F-4D93-AE8C-750588BF00QA/AM2020/Global_POVEQ_COL.pdf). [Last accessed on 16 Jun 2023].
28. Pan American Health Organisation (2022). WHO report shows poorer health outcomes for many vulnerable refugees and migrants. Available from: <https://www.paho.org/en/news/20-7-2022-who-report-shows-poorer-health-outcomes-many-vulnerable-refugees-and-migrants>. [Last accessed on 16 Jun 2023].
29. Pan American Health Organisation (2021). Afro-descendants in Latin American countries live in starkly unequal conditions that impact health and well-being, PAHO study shows. Available from: <https://www.paho.org/en/news/3-12-2021-afro-descendants-latin-american-countries-live-starkly-unequal-conditions-impact>. [Last accessed on 16 Jun 2023].
30. Arias-Orozco P, Bástida-González F, Cruz L, et al. Spatiotemporal analysis of canine rabies in El Salvador: violence and poverty as social factors of canine rabies. *PLoS One* 2018;13:e0201305. DOI PubMed PMC
31. Subedi D, Chandran D, Subedi S, Acharya KP. Ecological and socioeconomic factors in the occurrence of rabies: a forgotten scenario. *Infect Dis Rep* 2022;14:979-86. DOI PubMed PMC
32. Murillo-sandoval PJ, Gjerdseth E, Correa-ayram C, et al. No peace for the forest: rapid, widespread land changes in the Andes-Amazon region following the Colombian civil war. *Glob Environ Change* 2021;69:102283. DOI
33. de Thoisy B, Bourhy H, Delaval M, et al. Bioecological drivers of rabies virus circulation in a neotropical bat community. *PLoS Negl Trop Dis* 2016;10:e0004378. DOI PubMed PMC
34. Caicedo MR, Xavier DA, Arias Caicedo CA, Andrade E, Abel I. Epidemiological scenarios for human rabies exposure notified in Colombia during ten years: a challenge to implement surveillance actions with a differential approach on vulnerable populations. *PLoS One* 2019;14:e0213120. DOI PubMed PMC
35. Escobar Cifuentes E. La rabia transmitida por vampiros. *Biomédica*. Available from: [http://www.scielo.org.co/scielo.php?script=sci\\_arttext&pid=S0120-41572004000300001](http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0120-41572004000300001). [Last accessed on 16 Jun 2023] (in Spanish).
36. Blackwood JC, Streicker DG, Altizer S, Rohani P. Resolving the roles of immunity, pathogenesis, and immigration for rabies persistence in vampire bats. *Proc Natl Acad Sci U S A* 2013;110:20837-42. DOI PubMed PMC
37. World Health Organization, Food and Agriculture Organization of the United Nations, World Organisation for Animal Health and United Nations Environment Programme. One health joint plan of action (2022-2026): working together for the health of humans, animals, plants and the environment. Available from: <https://apps.who.int/iris/handle/10665/363518>. [Last accessed on 16 Jun 2023].
38. World Health Organisation. Ending the neglect to attain the sustainable development goals. One health: approach for action against neglected tropical diseases 2021-2030. Available from: <https://www.who.int/publications/i/item/9789240042414>. [Last accessed on 16 Jun 2023].
39. Lembo T; Partners for Rabies Prevention. The blueprint for rabies prevention and control: a novel operational toolkit for rabies elimination. *PLoS Negl Trop Dis* 2012;6:e1388. DOI PubMed PMC
40. Lembo T, Attlan M, Bourhy H, et al. Renewed global partnerships and redesigned roadmaps for rabies prevention and control. *Vet Med Int* 2011;2011:923149. DOI PubMed PMC
41. National Health Institute, Protocolo de la Vigilancia Integrada de la Rabia Códigos 300, 650, 652, 670, (2022). [online] Available from: [https://www.ins.gov.co/busador-eventos/Lineamientos/Pro\\_Vigilancia%20Integrada%20Rabia.pdf](https://www.ins.gov.co/busador-eventos/Lineamientos/Pro_Vigilancia%20Integrada%20Rabia.pdf). [Last accessed on 25 Jun 2023].
42. Centers for Disease Control and Prevention (U.S.). Workshop summary : prioritizing zoonotic diseases for multisectoral one health collaboration in Colombia. February 7, 2023. Available from: <https://stacks.cdc.gov/view/cdc/124926>. [Last accessed on 16 Jun 2023].
43. World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO) and World Organisation for Animal Health (OIE). Taking a multisectoral, one health approach: a tripartite guide to addressing zoonotic diseases in countries. ISBN: 978-92-4-151493-4. Available from: <https://www.who.int/publications/i/item/9789241514934>. [Last accessed on 16 Jun 2023].