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Global reduction in animal morbidity and mortality due to vaccine development (1950–2021): rinderpest, foot-and-mouth disease, avian influenza, and rabies

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Key words: animal vaccination, morbidity, mortality, rinderpest, rabies

Abstract

Over the past 70 years, veterinary vaccines have been crucial in controlling infectious diseases, ensuring food security, improving animal health, and promoting public health. This paper examines the global decline in morbidity and mortality in livestock and wildlife due to vaccination campaigns from 1950 to 2021. Data were gathered from peer-reviewed studies, international reports, case studies, and organizations such as the Food and Agriculture Organization (FAO). These sources helped assess trends in disease epidemiology and demonstrate vaccination's vital role in controlling or eradicating animal diseases and reducing zoonotic risks. Diseases studied include foot-and-mouth disease, rinderpest, avian influenza, and rabies. Findings show that global vaccination eradicated rinderpest in animals and wildlife, while foot-and-mouth disease and avian influenza declined by over 90% and 60%, respectively. The campaigns also prevented billions of dollars in economic losses annually by reducing outbreaks and mortality. This underscores the importance of sustained funding for veterinary vaccination programs to protect animal populations and human health alike.

Introduction

Vaccination is one of the most effective tools to protect domestic and wild animals from the burden of infectious diseases, and this plays a big role in veterinary public health maintenance.[1] From the middle of the 20th century, vaccines and vaccination globally have fundamentally altered the control of numerous deadly infectious diseases in animals. In addition to the protective role of vaccines in animals and controlling animal infectious diseases, vaccine has many other critical roles, such as an increase in the productivity of agriculture, international food security, and the prevention of transmitting zoonotic diseases from animal to human, which creates high risks in human health.[2]

Animal diseases may have destructive impacts on the rural livestock industry and the national economy when the disease spreads among livestock. In the areas where they heavily depend on the animal industry and agriculture, infectious disease outbreaks may lead to high morbidity and mortality and subsequently result in a decrease in productivity, increase costs on rural lives, and limit their market accessibility because of market restrictions during outbreaks.[3] The devastating animal infectious diseases that cause outbreaks in rural livestock are: avian influenza, Foot-and-Mouth Disease (FMD), rabies, and rinderpest.[4] The global livestock industry suffers financial losses in the billions of dollars yearly to prevent the spread of infectious diseases. These financial losses shouldered unfairly by small-scale farmers in low-and middle-income countries.[5]

In 2011, the Food and Agriculture Organization (FAO) and the World Organization for Animal Health (WOAH) declared the eradication of rinderpest in animals.[6] This indicated a milestone success in the animal industry to prevent animal disease through vaccination, and it was recognized as one of the best-achieving vaccine initiatives in the history of veterinary science.[7] This result shows the feasibility and long-term advantages of a global vaccination campaign. Following the complete control and eradication of rinderpest disease, efforts started to control several diseases in the same way, such as rabies, through widespread vaccination of dogs, and Peste des Petits Ruminants (PPR), also known as small ruminant plague in animals, which clarifies the effective role of vaccines in decreasing morbidity and mortality.

Current progress in the sciences of molecular biology has a role in the development of new types of vaccines, which are species-specific and more effective, such as recombinant and vector-based vaccines that ensure greater safety and immunogenicity.[8] These breakthroughs are critically important for addressing newly emerging infectious diseases and for protecting vulnerable animal populations.

More recently, breakthroughs in molecular biology and immunology have accelerated the development of novel vaccine platforms. Really, mRNA-based vaccines, recently popularized by COVID-19 vaccination, are now being explored in veterinary contexts; for example, the first mRNA vaccine for FMD has been successfully tested in cattle, offering rapid adaptability and safer production.[9] Vector-based and recombinant vaccines are also making strides: rabies virus has been engineered as a viral vector to express foreign antigens,[10] and recombinant Vaccinia–Rabies Glycoprotein Oral Vaccines (V-RG) have seen success in wildlife rabies control.[11] These new technologies promise higher specificity, better safety, and faster development compared to traditional vaccine types, though challenges remain in cost, regulation, and cold-chain requirements.[8,12]

This study aims to provide a comprehensive assessment of the reduction in morbidity and mortality in animals globally due to vaccine formulation and deployment from 1950 to 2021. By creating historical data, published studies, and reports from international organizations, this study highlights the significant progress made and emphasizes the need for sustained investment in vaccine development in veterinary fields and the vaccination foundation structure.

Materials and Methods

Retrieved data from available online information from 1950 to 2021 was used. The data were extracted from surveillance data from the animal health monitoring system, official reports from international health organizations such as FAO, WOAH, and Peer-reviewed studies were identified through targeted searches of PubMed, Scopus, and Web of Science using disease- and vaccination-related keywords, and to describe both quantitative and qualitative analytical approaches. The data were aggregated to evaluate trends in animal disease occurrence and mortality rates across different regions. The vaccine-linked rinderpest eradication was used for a comparative insight as a case study. Descriptive statistics were utilized to determine the extent of reduction; meanwhile, qualitative analysis provided a framework for interpretation.

Results

Rinderpest

Rinderpest is a devastating viral disease of some animals, such as cattle and wildlife.[13] It was declared that rinderpest had been eradicated a decade ago (2011) through a successful coordination of the global vaccination program and campaigns (Figure 1).[6,14,15] This disease is declared as a first eliminated animal viral disease, and it is believed to save millions of animals and livestock every year and prevent yearly economic losses estimated at one billion dollars (Table 1, Figure 1).[6,16]

Rabies

A key strategy to control rabies is the mass dog vaccination program, implemented in many countries across Africa and Asia. These initiatives have led to a substantial reduction in rabies among canines, which in turn has contributed to a global decline in human rabies cases by approximately 51.6%, falling from 21,813 deaths in 1980 to 10,084 in 2021 (Figure 2).[18] A notable example comes from Bangladesh, where human rabies mortality has decreased by nearly 50% following nationwide canine vaccination campaigns (Table 1).[19-21] According to continent-level estimates from Our World in Data, derived from the Global Burden of Disease (GBD) 2024 study of the Institute for Health Metrics and Evaluation (IHME), marked heterogeneity is observed in human rabies mortality trends between 1980 and 2021. The tabulated figures highlight substantial declines in Asia, the Americas, and Europe, while Africa exhibits a moderate increase, and Oceania shows a small absolute rise despite low baseline numbers. This regional variation underscores the uneven progress in rabies control and the need for tailored prevention strategies (Table 2).[18,19]

Avian influenza

Mass vaccination campaigns against H5N1 Highly Pathogenic Avian Influenza (HPAI) in countries like Egypt, China, and Vietnam have played a crucial role in controlling the spread of the virus in poultry populations.[22,23] These vaccination efforts have significantly reduced clinical disease and mortality rates, helping to protect both commercial and household poultry. In regions where vaccination coverage was substantial, outbreaks have decreased markedly, contributing to improved

food security and the livelihoods of rural communities.[23-25] Additionally, vaccination has helped reduce the risk of zoonotic transmission to humans by controlling viral circulation in domestic birds.[22,23] Combined with enhanced surveillance and biosecurity measures, vaccination serves as an essential tool within comprehensive strategies to manage and eventually eradicate HPAI, maintaining poultry health and supporting public health efforts.[23-25]

Control of HPAI traditionally combines rapid diagnosis, surveillance, culling of infected flocks, strict biosecurity, and training of poultry workers. Pre-emptive culling around affected areas remains a key containment tool. Vaccination against H5N1 was first introduced in Hong Kong in 2002, and between 2002 and 2010 over 113 billion doses were administered across 15 countries covering 131 billion birds. The average national coverage was about 42%, with a global coverage of 11% among vaccinating nations. Nearly all vaccines were used in four countries: China (91%), Egypt (4.6%), Indonesia (2.3%), and Vietnam (1.4%), reflecting the regional concentration of the H5N1 panzootic.[25]

Foot-and-mouth disease

Regional eradication of FMD was obtained in South American countries through continuous vaccination campaigns against FMD. The incidence of the disease fell to near zero in the vaccinated animal populations from 1980 to 2010. This results in improving livestock productivity and trade access (Table 3).[26,27]

In Brazil, FMD became endemic, and National vaccination programs began in 1988, with systematic mass vaccination of cattle supported by PANAFTOSA.[28] A major improvement came in the early 1990s with the introduction of oil-adjuvant vaccines, which sharply reduced outbreaks. Despite setbacks during the 2000–2001 epidemic, sustained vaccination campaigns enabled Brazil to achieve recognition as FMD-free with vaccination by the WOAH in 2018, and the country is now advancing toward FMD-free status without vaccination.[26-28] The WOAH provides official data showing global FMD status, distinguishing countries free with vaccination from those free without vaccination (Figure 3). The 2025 map illustrates the continued importance of vaccination and surveillance.[26,29]

Other emerging successes

Global Alliance for Livestock Veterinary Medicines (GALVmed) and some other organizations' efforts to create and distribute vaccines against some neglected tropical diseases have reduced morbidity, disease outbreaks, and economic losses in endemic areas for many diseases, such as Rift Valley fever and East Coast fever (Table 1).[30,31]

Discussion

In the past several decades, vaccinations have revolutionized the animal industry by controlling and preventing several highly infectious and lethal viral diseases and saving billions of dollars in losses. The landmark of success of vaccination is the complete eradication of rinderpest. This reveals the efficacy of the global vaccination campaign to eliminate infectious diseases. In turn, this effort saved the lives of millions of cattle and wildlife and guided future and similar initiatives.[32]

Rabies is considered a zoonotic viral disease that is transmitted from canines to humans, and it is a priority to control it.[33] Mass vaccination efforts against rabies, especially in Africa and Asia, have effectively reduced fatalities in both animals and humans.[18,19,34] Sustained international cooperation and investment are necessary to achieve the global objective of eradicating dog-associated human deaths by 2030.

Avian influenza remains a persistent challenge due to its zoonotic role and pace of its spread in poultry, particularly in poultry houses.[35] This rapid spread and high mortality were significantly contained and controlled in some endemic countries through vaccination programs, such as China and Egypt.[23,24] In spite of the fact that the disease is not completely eradicated, the viral load and transmission risk are reduced, and good control strategies are created to prevent devastating outbreaks and mortalities.

FMD incidence has been significantly reduced by >90% in some countries where a vaccination program and a sustained vaccination campaign are used. South America is one of the regions that successfully controlled the disease and experienced good progress in the program. Several regions in South America have been officially declared free from FMD following sustained vaccination campaigns.[26,36]

The vaccination program has also been transferred to several other viral diseases in animals called neglected tropical diseases, such as Newcastle Disease, East Coast fever, and Rift Valley fever. Newcastle has one of the highest incidences among poultry in low-income countries.[37] This campaign is supported by international organizations, such as GALVmed. This effort improves animal productivity and rural income in the animal and poultry industry in low-income countries. This disease was out of global attention, but it causes losses of animal productivity in local regions in poor countries. Advances in vaccine production in the modern world, such as producing cheap and thermostable vaccines, have made access to animal vaccination possible everywhere.[38]

In sum, these cases demonstrate how vaccines enhance animal and human health while strengthening food security and economic stability. Nevertheless, enduring problems include cold chain requirements, vaccine hesitancy, emerging pathogen threats, and infrastructure limitation is a remaining challenge.[2,7] Responding to these barriers will be essential to uphold the past decade's gains and plan for future disease challenges.

Conclusions

Evidence from animal disease control programs clearly demonstrates the substantial impact of vaccination on veterinary medicine and the livestock sector. This impact is exemplified by the complete eradication of rinderpest and by the marked reduction in cases of FMD and avian influenza in vaccinated regions. Vaccination programs reduce animal morbidity and mortality, mitigate public health risks, and prevent major economic losses. Future efforts should prioritize the expansion of large-scale vaccination programs, the development of affordable and thermostable vaccines for infectious diseases, and the strengthening of surveillance systems, particularly in low-income countries, to build upon these achievements.

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Table 1. Summary of the global impact of animal vaccination on major devastating animal viral diseases. The table summarizes the impact of vaccination programs on rabies (canine rabies), Highly Pathogenic Avian Influenza (HPAI), Foot-and-Mouth Disease (FMD), East Coast Fever (ECF), and Rift Valley Fever (RVF). Contributions from international organizations include the Global Alliance for Livestock Veterinary Medicines (GALVmed), the International Livestock Research Institute (ILRI), the United Kingdom's Department for International Development (DFID), and the Bill & Melinda Gates Foundation.

Disease	**Vaccine Introduction**	**Estimated Reduction in Mortality**	**Outcomes**
Rinderpest	Widespread by the 1950s	100% eradicated by 2011	It is the First and only eradicated animal disease, and prevents one billion dollars in losses annually
Rabies (Canine)	1980s to present	Global vaccination campaigns; ~90% coverage in vaccinated areas of Bangladesh	51.6% decline in human fatalities globally; ~50% decline in Bangladesh
Avian Influenza (HPAI)	Early 2000s	Mass poultry vaccination in Egypt, China, and Vietnam reduced clinical disease, mortality in poultry, and zoonotic transmission. Human vaccination, improved care, and surveillance	Progress in the protection of the poultry industry in vaccinated areas

		reduced fatality rates.	
Foot-and-Mouth Disease	1980s to present	> 90% in South America	FMD-free countries are achieved: Trade and Productivity benefit
East Coast Fever	Developed >30 years ago; production & delivery improved through GALVmed/ILRI with DFID & Gates Foundation support	Potential to save >1 million cattle and US$260 million annually; reduces calf mortality (20–50% in unvaccinated herds)	Major threat to >25 million cattle in eastern, central, and southern Africa; crucial for livelihoods and dairy farmers
Rift Valley Fever	New Clone 13 vaccine (recently registered in South Africa); tested in Kenya in cattle, sheep, and goats	>90% immunogenicity in sheep and goats, ~67% in cattle; safe with minimal adverse effects	Key for preventing RVF epidemics; safer alternative to the Smithburn vaccine; protects livestock and human livelihoods in endemic regions

Table 2. Human deaths from rabies by continent in 1980 and 2021, with absolute and relative changes (%). Data source: Institute for Health Metrics and Evaluation (IHME), Global Burden of Disease, 2024.

Region	**1980**	**2021**	**Absolute Change**	**Relative Change (%)**
African Region	3039	3515	+474	+15.66%

South-East Asia	15214	4855	-10,359	-68.09%
European Region	42	17	-25	-59.52%
Americas	346	8	-338	-97.69%
Eastern Mediterranean	1332	737	-595	-44.67%
Western Pacific	1836	950	-886	-48.26%
Total	21,809	10,081	-11,728	-53.78%

Table 3. Timeline of Foot-and-Mouth Disease (FMD) Eradication and World Organization for Animal Health (WOAH) Recognition in South America, 2011–2020. This table summarizes the last reported outbreaks of Foot-and-Mouth Disease (FMD) and subsequent years of recognition of FMD-free status by the World Organization for Animal Health (WOAH) in selected South American countries during the Hemispheric Program for the Eradication of Foot-and-Mouth Disease (PHEFA) Action Plan (2011-2020). The 'Year of Eradication' column highlights either the year of the last outbreak or the year of WOAH recognition, providing evidence of vaccination impact and regional progress toward eradication.

Country	**Last Outbreak (Year)**	**Year Recognized as FMD-Free (WOAH)**	**Status**
Ecuador	2011	-	Last outbreak in 2011
Paraguay	2012	-	Last outbreak in 2012
Venezuela	2013	-	Last outbreak in 2013

Bolivia	-	2014	WOAH recognition FMD-free with zones vaccination/no vaccination
Ecuador	-	2015	WOAH recognition FMD-free with zones vaccination/no vaccination
Brazil	-	2018	WOAH recognition FMD-free with zones vaccination/no vaccination
Surinam	-	2018	WOAH recognition FMD-free without vaccination
Peru	-	2018	WOAH recognition FMD-free without vaccination
Brazil	-	2018	WOAH recognition FMD-free with zones vaccination/no vaccination
Colombia	2018	-	Last outbreak in 2018

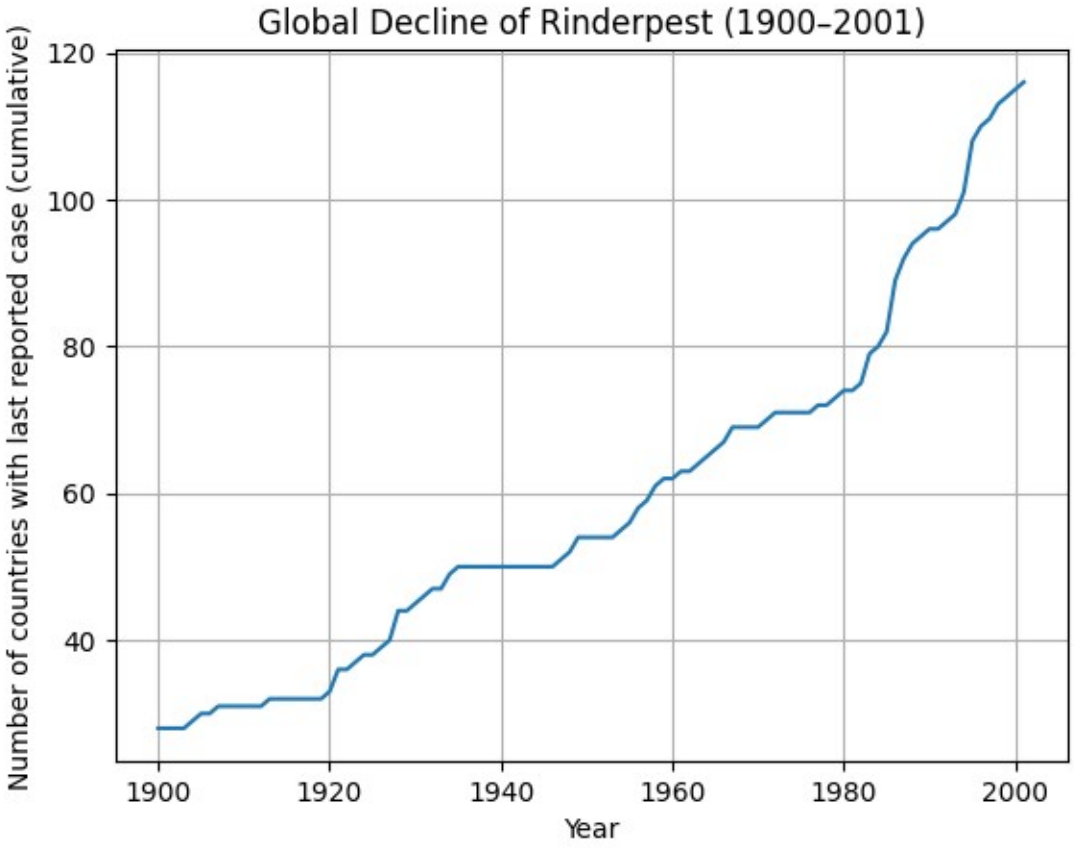

Figure 1. Global decline in rinderpest occurrence (1900–2001).

The figure shows the cumulative number of countries reporting their final recorded rinderpest case over time, highlighting the progressive global elimination of the disease and its eventual eradication in 2001. Data derived from the World Organisation for Animal Health and Food and Agriculture Organization of the United Nations, processed by Our World in Data (2022).[17]

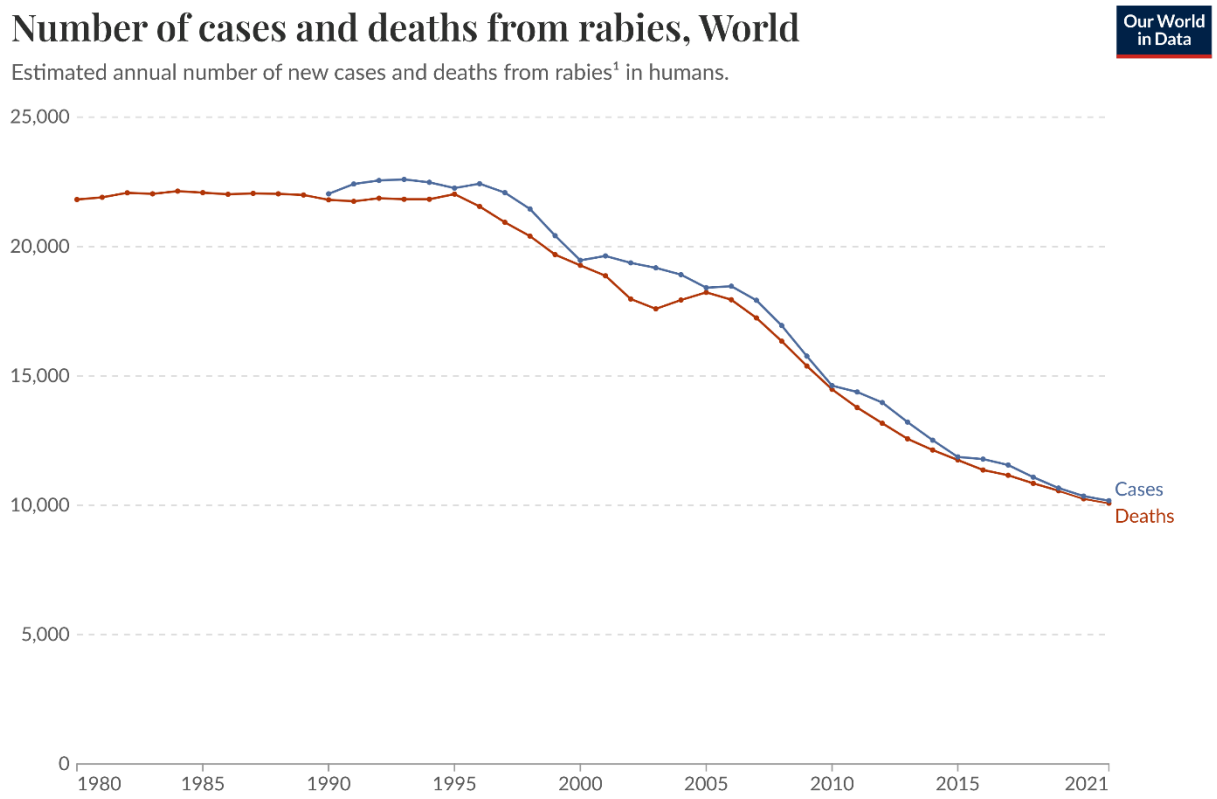

Figure 2. Estimated annual number of human rabies cases and deaths worldwide, 1980–2021. The figure illustrates the global burden of rabies over time, showing both incidence and mortality trends. Data are derived from the Global Burden of Disease (GBD) study, with processing and visualization by Our World in Data. Source: Our World in Data (CC BY 4.0), based on data from the Global Burden of Disease (IHME, 2024).[18] Available at: OurWorldinData.org.

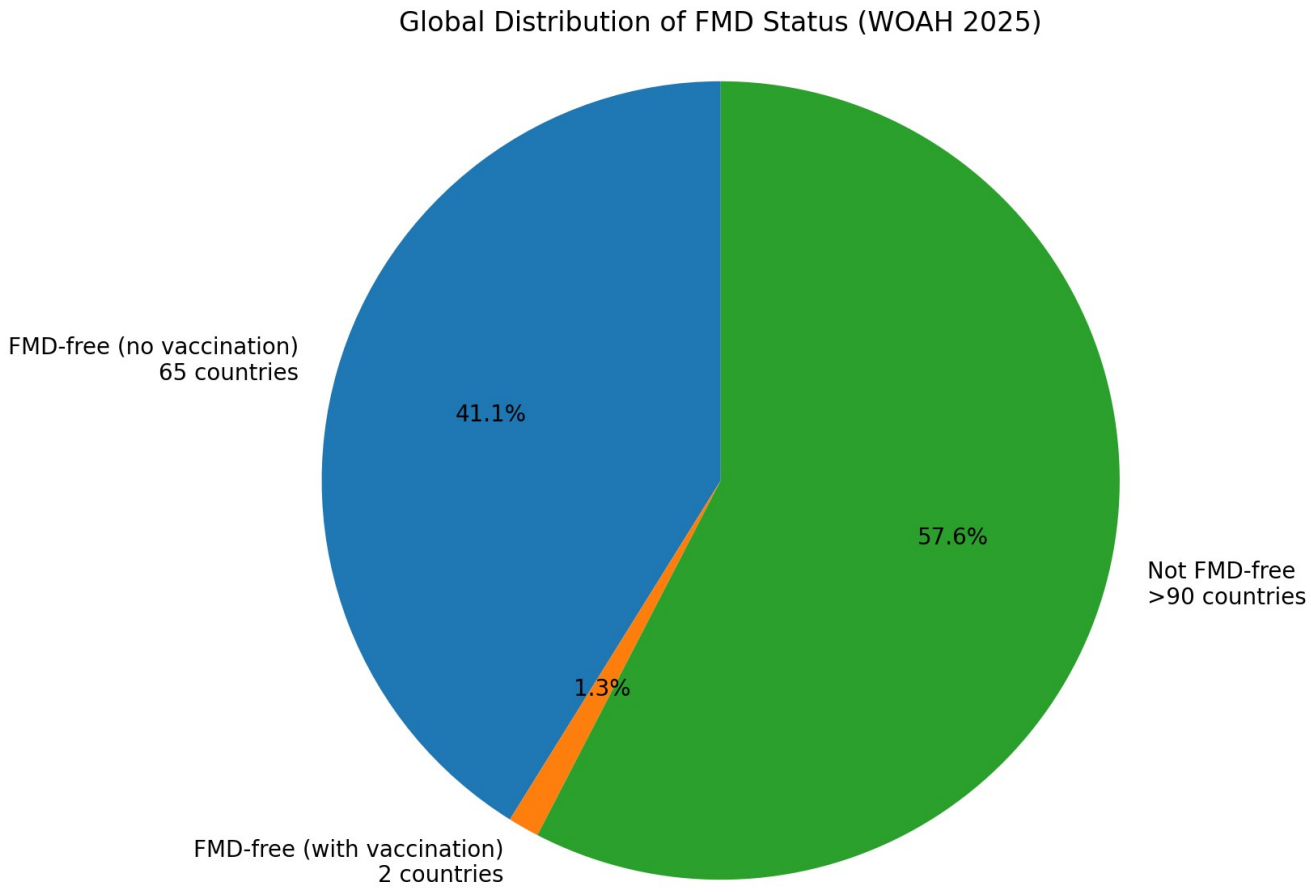

Figure 3. Global distribution of countries by foot-and-mouth disease (FMD) status, categorized according to vaccination policy. The chart illustrates the number of countries officially recognized as FMD-free without vaccination and those maintaining vaccination programs, as well as countries without recognized FMD-free status. Classification is based on official disease status reports published by the World Organisation for Animal Health as of 2025.[26]

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