1 Global Dog and Human Rabies Control Efforts from Ancient Times to 2030 and Beyond

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Abstract
Nowadays, rabies is mainly present in Africa and Asia, where every year it causes an estimated 59,000 human deaths and costs US$8.6 billion. A key date in the history of rabies control is 6 July 1885, when the first dose of rabies vaccine was successfully inoculated to an exposed individual in Paris. Yet, long before and after this event, many attempts at stopping rabies transmission, managing dog bites and preventing rabies symptoms have occurred throughout the world. Each step forwards – and backwards too – has been crucial to advance the scientific knowledge of rabies and how to control this disease at the interface of challenges of ecological, political and social nature. As the world starts to recover from the coronavirus 2019 (COVID-19) pandemic and move towards the 2030 goal of eliminating dog-mediated human rabies, learning from the past is vital for achieving a world with reduced rabies risk.

1.1 Current Epidemiological Situation

The rabies virus (RABV) belongs to the order *Mononegavirales* (which are viruses with non-segmented, negative-stranded RNA genomes), the family *Rhabdoviridae* (which groups bullet-shaped viruses), and the genus *Lyssavirus* (Fooks and Jackson, 2020). Rabies is a viral zoonotic disease most often transmitted through the bite of a rabid animal, but transmission can also occur through licks, scratches, or the contamination of mucosa or open skin wounds with infectious saliva. RABV affects mammals, including humans, by infecting their central nervous system and ultimately causing inflammation of the brain and death. In humans, the incubation period of the disease can vary from 1 week to 1 year, though it is typically 2–3 months. In dogs, the incubation period is usually shorter.

Clinically, rabies has two forms: (i) furious rabies, with hyperactivity, hallucinations, hydrophobia (fear of water), and sometimes aerophobia (fear of drafts or fresh air); and (ii) paralytic rabies, characterized by growing paralysis. The paralytic form of rabies is often misdiagnosed, contributing to the under-reporting of the disease in humans and the underestimation of the disease in dogs. In each form, once the symptoms of the disease develop, rabies is incurable and fatal to both animals and humans. However, rabies is 100% preventable in humans through thorough wound washing with water and soap,

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as well as post-exposure prophylaxis (PEP), which includes the use of rabies vaccine and immunoglobulins (WHO, 2018b).

Rabies is widely distributed across the world. It is estimated that 59,000 people die of rabies each year, mainly in Asia (59.6%) and Africa (36.4%) (Hampson *et al.*, 2015). The number of dogs and other mammals who die of it is unknown. Most human deaths, 99%, are caused by exposure to an infected dog. About 40% of human victims are children under the age of 15. Most human victims are males and belong to geographically, economically and socially marginalized areas (WHO, 2018b).

Rabies costs US$8.6 billion globally each year (Hampson *et al.*, 2015). About half of this cost is for medical care and this mainly includes the direct cost of care, where the average cost of the whole vaccination schedule (not including immunoglobulin) is estimated at US$108. When this cost is borne out-of-pocket by patients, it can be catastrophic in low-income settings. When PEP is provided for free by government healthcare facilities, it represents a substantial expenditure for health systems, especially the under-resourced ones. Medical care-related cost also includes lost income while seeking care, and the cost of travelling to the healthcare facility. Fifty-four per cent of the total cost is incurred through productivity losses due to premature death. When the victim is the main income earner in the family, their death can easily push the relatives into deeper poverty. Most of the remaining cost is caused by the loss of infected livestock, which can severely affect the economic stability of rural families. In addition to this, psychological trauma for individuals and their communities must be taken into account, even though it remains uncalculated.

1.2 History of Rabies and Rabies Control in Ancient Times

As one of the oldest infectious diseases and zoonoses known to humans, rabies is referenced in a wide range of texts spanning most of early human civilization (King *et al.*, 2004; Wasik and Murphy, 2012; Tarantola, 2017), with possible close links to the history of the domestication of dogs (Rupprecht *et al.*, 2020). The disease is documented in texts from diverse locations, such as the laws of Eshunna from ancient Sumerian and Akkadian civilizations (1930–1770 BCE) in present-day Iraq (Tarantola, 2017), the *Susruta Samhita*, an ancient Indian treatise on Ayurveda (1000 BCE – first or second century CE) and a medical treatise of the Greek philosopher Aristotle (384–322 BCE) (King *et al.*, 2004), among others (Pankhurst, 1970; Liu, 2013). All these texts recognize the links between the bite of a rabid animal and the development of rabies symptoms. Indeed, an Arabic translation of the Greek physician Dioscorides' (40–90 CE) *De Materia Medica* includes a drawing of a rabid dog biting a man (Tarantola, 2017). These texts also recognize the existence of a latent or incubation period between bite exposure and the development of symptoms, and that once symptoms of rabies, such as hydrophobia, develop in human patients, death is inevitable. Furthermore, the disease was often considered a punishment from the gods, a belief that persists in some communities today (Nadal *et al.*, 2022b). Perhaps as a consequence, treatments often comprised religious chants as well as herbal remedies or procedures such as applying parts from the brain of the biting dog to bite wounds (Wasik and Murphy, 2012) or sucking out the 'poison' injected through the bite. Notably, the *Susruta Samhita* and Dioscorides proposed cauterizing bite wounds as a treatment for rabies. Avoiding dog bites was recognized as an essential preventive measure in the Persian Avesta (200–400 CE) (Tarantola, 2017).

In subsequent centuries, there was little progress in advancing the understanding of the prevention or treatment of rabies, although the importance of washing wounds after animal bites was increasingly recognized from the Renaissance period in Europe. This latter period also saw an increase in the scientific understanding of the pathophysiology of the disease (Tarantola, 2017).

Rabies was thus probably enzootic throughout most parts of ancient Asia, the Middle East and Europe. The history of rabies in the African continent is less clear. Dog rabies appears to have been known in the Mediterranean Basin, North Africa (King *et al.*, 2004), such as in ancient Egypt nearly 5000 years ago (Tarantola, 2017; Rupprecht *et al.*, 2020), Kenya (Kuwert *et al.*, 1985) and in 18th-century Amharic texts in

Ethiopian communities (Pankhurst, 1970). In contrast, British travellers visiting southern Africa in the early 19th century commented on the absence or relative rarity of canine rabies in this part of the world. This lack of historical knowledge about rabies in Africa may partly have been due to the inability of extant Europeans to engage with the rich oral traditions of African communities at the time (Brown, 2011). Later on, canine rabies became established throughout Africa after the European colonization. This is also true of North, Central and South America, the Caribbean and Australia, where canine rabies was rare, if at all present, and the disease appears to have been maintained only by bats and other wildlife hosts (Rupprecht *et al.*, 2020).

1.3 History of Rabies Control in the Victorian Period in the UK and the Colonization Period in Asia and Africa

With the advent of European sea travel and eventual colonialism, there are increasing records of canine rabies caused by RABV in sub-Saharan Africa and the Americas, as well as detailed descriptions of canine rabies in several regions in Asia (Kuwert *et al.*, 1985; Ward, 2014; Rupprecht *et al.*, 2020; Dande, 2021). At the same time, rabies was also reported in various wildlife hosts (Rupprecht *et al.*, 2020), resulting in sustained attempts to cull wildlife (Kuwert *et al.*, 1985; Brown, 2011; Radhakrishnan *et al.*, 2020). British military personnel and doctors frequently recorded details of cases of human and animal rabies, such as in India, and various forms of treatment were vigorously debated in medical circles (Radhakrishnan *et al.*, 2020). As a result, rabies control efforts generally consisted of removing or destroying dogs or wildlife, implementing laws restricting dog movement and requiring owned dogs to be muzzled in public (Pemberton and Worboys, 2007; Radhakrishnan *et al.*, 2020; Rupprecht *et al.*, 2020). Such preventive measures were especially successful in eliminating dog-mediated human rabies in a number of Scandinavian countries in the early 1800s (King *et al.*, 2004) and the UK by 1902 (Pemberton and Worboys, 2007), well before the development of preventive animal rabies vaccines.

Before its elimination, canine rabies was common in the Victorian period of the UK, and several people died of dog-mediated rabies every year (King *et al.*, 2004). The disease was frequently attributed to the allegedly irresponsible way poor and working-class persons reared 'curs' – mongrels with no particular breed characteristics. In many ways, rabies was thus often conflated with poverty, low class and criminality (Pemberton and Worboys, 2007). In the 1830s, legislation requiring dogs to be muzzled was viewed as symbolic of political or gender-based oppression and was often opposed. Later, such measures were also objected to on the grounds of animal welfare. While public concern over rabies in the UK waxed and waned in the intervening decades, by the late 1890s, there were concerted efforts to eliminate dog rabies from the country. Nevertheless, there continued to be vehement opposition to the implementation of muzzling laws. However, in combination with laws requiring the registration and confinement of dogs and quarantine of imported animals, such legislation caused a gradual decline in the number of dog and human rabies cases. In 1900, no rabies cases were reported in England and Wales. The last indigenous cases of animal rabies were reported in 1902 in South Wales (Pemberton and Worboys, 2007).

While similar control measures were implemented in colonies in Asia and Africa, there appears to have been limited success in controlling the spread of rabies (Brown, 2011; Radhakrishnan *et al.*, 2020). In Africa, measures such as 'tie up' orders for free-roaming dogs, most of which were owned, were unpopular (Brown, 2011; Rupprecht *et al.*, 2020; Dande, 2021). In the early 1890s, an outbreak of dog rabies in Port Elizabeth in present-day South Africa prompted authorities to enforce the muzzling of all dogs, movement restrictions, licensing of owned dogs and destruction of 'stray' or unmuzzled dogs. As observed in the UK, such measures disproportionately targeted poorer African neighbourhoods and their indigenous breed dogs, which were viewed as inferior or diseased and often considered vermin to be exterminated (Brown, 2011; Dande, 2021). In British India, where canine rabies was enzootic, legislation permitting the destruction of ownerless dogs was present as early as 1813. Other measures, such as levying a dog tax and issuing badges for owned dogs, were also attempted with limited success (Radhakrishnan *et al.*, 2020).

The pioneering work of Louis Pasteur, Emile Roux and other colleagues in developing the first human rabies vaccine in 1885 led to the establishment of Pasteur Institutes worldwide (Tarantola, 2017). These institutes enabled the PEP of bitten individuals and prevented countless human rabies deaths. The first patients outside Europe to receive PEP were two children in Saigon (present-day Ho Chi Minh City, Vietnam) in 1891 (Tarantola, 2017). Pasteur's vaccine was improved upon by various scientists (Tarantola, 2017), most notably David Semple at the Pasteur Institute in Kasauli, British India, established in 1900. At one point, the Kasauli institute treated more rabies patients than any other Pasteur Institute globally. The Semple vaccine itself was used for decades worldwide for human PEP. Its use was discouraged by the World Health Organization (WHO) in the 1980s because of its severe adverse side effects and its lower efficacy compared to modern cell culture vaccines. Many countries, such as India, officially discontinued its use only in the new millennium, so the memory of the 14 painful injections into the abdomen required by the nerve tissue vaccine is often still vivid nowadays. This may negatively affect access to PEP by at-risk individuals (Nadal, 2018), so awareness campaigns need to address this issue.

The development and use of human rabies vaccines were followed by experimental efforts in British India, Japan, the USA and Italy to develop animal rabies vaccines to prevent disease in primary animal reservoirs, particularly dogs (Radhakrishnan *et al.*, 2020). The first dog rabies vaccine was developed in Japan and later refined for use in preventive mass dog vaccination in this country from the early 1920s (Kurosawa *et al.*, 2017) and 1930 in Taiwan (then a Japanese colony) (Liu, 2013). However, while animal rabies vaccines were used to treat valuable pets or livestock (Radhakrishnan *et al.*, 2020), there is little evidence from the early 1900s for similar attempts at dog mass vaccination in colonies in Asia and Africa. In these regions, rabies control continued to rely on the culling of dogs and wildlife, restriction of dog movement and attempts to regulate dog ownership (Brown, 2011; Radhakrishnan *et al.*, 2020).

1.4 History of Rabies Control After Independence in Asia and Africa

Following the development of animal rabies vaccines, mass dog vaccination gradually became an invaluable tool for canine rabies control. The successful elimination in 1957 of animal rabies in Japan through mass vaccination (in combination with other measures described above) (Kurosawa *et al.*, 2017) and similar efforts in the USA (Rupprecht *et al.*, 2020) provided proof of concept for the possibility of rabies elimination. In the 1940s, red fox (*Vulpes vulpes*) rabies emerged as a significant concern in North America and Europe (King *et al.*, 2004), prompting the development of oral rabies vaccines (ORV) during the 1970s. Following the first successful ORV field trial in 1978 in Switzerland, ORV campaigns during the 1980s and 1990s steadily eliminated wildlife rabies in Western Europe (King *et al.*, 2004). In South American and Caribbean countries, the implementation of mass dog vaccination and enhanced disease surveillance efforts from the 1980s, coordinated by the Pan American Health Organization (PAHO), has resulted in significant reductions in human and canine rabies deaths in the region (Del Rio Vilas *et al.*, 2017; Rupprecht *et al.*, 2020). In 2016, Mexico reported its last case of canine rabies caused by RABV (Rupprecht *et al.*, 2020). With increasing evidence of the futility and inhumanity of culling for rabies control (Morters *et al.*, 2013), attention has shifted globally to using humane population management strategies such as surgical or chemical animal birth control to support mass dog vaccination campaigns (WHO, 2018b). Other recent developments have included the adoption of dose-sparing intradermal rabies vaccines for human PEP (WHO, 2018a), the development of rabies monoclonal antibodies (Dias de Melo *et al.*, 2022), and research on the control of bat rabies in South America using vaccines and reproductive suppressants (Benavides *et al.*, 2020).

Despite these developments, rabies control efforts in large parts of Asia and Africa have been haphazard and uncoordinated (Kuwert *et al.*, 1985). In the decades after the Second World War (1939–1945), several Asian and African regions gained independence from colonial rule. In these newly independent countries, nearly all of which were poor and economically underdeveloped, rabies was among a host of competing health priorities. As a result, the disease remained under-prioritized by various national and regional public health authorities. Despite the availability of effective canine rabies vaccines, rabies control has continued to rely on population reduction methods such as culling dogs or wildlife and vaccination of owned dogs (Kuwert *et al.*, 1985; Rupprecht *et al.*, 2020). While some countries have never managed to control rabies, some nations eliminated it at local or national levels, while others have seen outbreaks of dog or wildlife rabies occur in areas previously free of the disease (Yang *et al.*, 2018; Rupprecht *et al.*, 2020).

Rabies spread throughout southern Africa in the 1940s and 1950s, moving through present-day Angola, Zambia, Namibia, Botswana, Zimbabwe, Mozambique and South Africa (Brown, 2011). In the face of new rabies outbreaks, canine vaccines were first imported from the USA by Southern Rhodesia (present-day Zimbabwe) for mass dog vaccination campaigns, followed by Bechuanaland (present-day Botswana) and South Africa (1952) (Brown, 2011). At the same time, authorities also taxed dog owners and killed free-roaming dogs. As before, such measures affected native African dog owners and their dogs more severely, so local Africans opposed these measures or actively circumvented them (Dande, 2021). Such actions significantly reduced the effectiveness of rabies control efforts in these areas. Similar vaccination campaigns, combined with the destruction of free-roaming dogs, have also been conducted in Kenya, Tanzania and various other African nations from the 1950s onwards. Still, canine rabies remains enzootic in these regions (Kuwert *et al.*, 1985). Field trials in some African countries have demonstrated the value of ORV for dog rabies control on the continent, as a complementary measure to parenteral vaccination useful to target hard-to-catch free-roaming dogs (Cliquet *et al.*, 2018). In 2015, the Pan African Rabies Control Network (PARACON) was established as a network of rabies experts in Africa to strengthen and streamline rabies control efforts on the continent.

In Asia, the picture has been more heterogeneous. Only Japan and Singapore are rabies free. In India, which gained independence in 1947 and nowadays accounts for one-third of the global human rabies burden (Hampson *et al.*, 2015), rabies control was first discussed in the national 5 year plans for national development only in 2002. Although dog culling was outlawed in 2001, reactive culling continues to occur throughout the country, and animal vaccination has consistently focused on owned dogs, but with very low vaccination coverage (Radhakrishnan *et al.*, 2020). India's first formal policy for rabies control was released only in 2021 when human rabies was also made notifiable (Benavides *et al.*, 2020). The Indian approach to rabies control, and overall dog population management, is currently characterized by a strong focus on dog population control (Nadal, 2020). In 2008, the previously rabies-free island of Bali in Indonesia reported its first dog rabies outbreak, resulting in mass dog vaccination campaigns and widespread dog culls that have so far failed to control the disease (Ward, 2014). In contrast, Taiwan was free of canine rabies from 1961 until the emergence of the disease in ferret badgers (*Melogale moschata*) in 2013 (Liu, 2013). Similarly, Malaysia lost its rabies-free status after the declaration of a rabies epidemic in 2015. Canine rabies continues to be enzootic in China (Liu, 2013) and several other Asian countries (Yang *et al.*, 2018). Like in Africa, field trials in Sri Lanka, the Philippines and Thailand have demonstrated the potential benefits of ORV for canine rabies control (Cliquet *et al.*, 2018). In 2018, some Asian countries followed the example of PARACON and formed the Asian Rabies Control Network (ARACON).

1.5 The Zero by 30 Goal

In 2015, the world called for action by setting the global goal of achieving zero human dog-mediated rabies deaths by 2030 (WHO and OIE, 2015). In 2018, the Tripartite (the Food and Agriculture Organization of the United Nations (FAO); the World Organization for Animal Health (WOAH), previously OIE; and the WHO) joined forces with the Global Alliance for Rabies Control (GARC) under the United Against Rabies

Forum (Tidman *et al.*, 2022) and launched the *Zero by 30: the Global Strategic Plan to End Human Deaths from Dog-mediated Rabies by 2030* (WHO *et al.*, 2019). Tools and expertise are provided to rabies-endemic countries to empower, engage and enable them, according to their budget, capacity and local context, to control rabies in dogs and eliminate the human burden of this disease.

As we read in the document, the rationale for rabies elimination is that rabies is 100% preventable with the current tools and knowledge, but still, it takes many human lives, especially among the world's most vulnerable populations. Eliminating rabies also strengthens health systems because the same infrastructure built to provide human vaccination, dog vaccination and community awareness in marginalized settings can be used for responding to other human and animal health needs, including emerging zoonoses, at the local level. Moreover, rabies elimination is considered a model for One Health collaboration and it is also aligned with the United Nations Sustainable Development Goal 3 – to 'ensure healthy lives and promote well-being for all at all ages' – and 1 – to 'end poverty in all its forms' without leaving anyone behind.

The plan has three objectives. The first is to use vaccines, medicines, tools and technologies effectively. Human rabies risk will be reduced by improving awareness, increasing access to healthcare and mass vaccinating dogs – in a One Health fashion. The second objective is to generate, innovate and measure impact, by ensuring reliable data to enable effective decision making. The third objective is to sustain commitment and resources, by harnessing multi-stakeholder engagement. Countries are expected to mobilize domestic and international resources to sustainably finance their rabies control activities.

The path towards the 2030 goal is divided into three phases. In 2018–2020, the Start Up phase involves the building of a strong foundation for rabies elimination by preparing and improving normative tools and structures to catalyse action, such as robust, budgeted, effective and sustainable national rabies elimination plans following a One Health approach. In 2021–2025 in the Scale Up phase, the plan reaches its maturity, thanks to the learning and experience gained along the way, and goes global. In 2026–2030, the Mop Up phase is the last mile, where remaining countries will be engaged and supported in the achievement of 'Zero by 30'.

1.6 The One Health Approach

As a concept – human, animal and environmental health are deeply interlinked – One Health goes as far back as ancient Greece, if not pre-modern times. As a phrase, it was formalized in 2004, when the Wildlife Conservation Society held the 'One World, One Health' meeting in New York City and issued the 'Manhattan Principles', 12 recommendations that included the need to look at human, animal and environmental health as a unit, and to adopt interdisciplinary approaches to disease prevention, health awareness and policy development (Bresalier *et al.*, 2021).

In 2022, the One Health High-Level Expert Panel, an interdisciplinary body created to advise the Quadripartite (which consists of the Tripartite and the newly added United Nations Environment Programme, UNEP), proposed a working definition for One Health. This definition is as follows:

> One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilizes multiple sectors, disciplines, and communities at varying levels of society 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.
>
> (OHHLEP *et al.*, 2022)

Many examples are available across the different areas of One Health application, including rabies elimination, to demonstrate the efficacy, sustainability and cost-saving of the interventions that adopt this approach. Strengthening and expanding the operationalization of One Health and giving programmes the political, financial and organizational stability that they need to achieve their target is now the priority. The 4Cs of Communication, Coordination, Collaboration and Capacity building are instrumental to this next step (OHHLEP *et al.*, 2022).

In late 2022, the Quadripartite launched the *One Health Joint Plan of Action (2022–2026): Working Together for the Health of Humans, Animals, Plants and the Environment* to create a framework to integrate systems and capacity for better preventing, predicting, detecting and responding to health threats, while contributing to sustainable development (WHO *et al.*, 2022). Rabies elimination is part of Action Track 2, 'Reducing the risks from emerging and re-emerging zoonotic epidemics and pandemics'.

1.7 Impact of the COVID-19 Pandemic on Rabies Elimination Efforts

The pandemic has taken the lives not only of the 6.5 million people who died of COVID-19 but also of those who couldn't access the healthcare services they needed, or couldn't receive the necessary healthcare due to the overwhelming pressure of the crisis on health systems. Low- and middle-income countries experienced this double effect of the pandemic more than rich ones. Further, as rabies is a notorious disease of poverty, rabies-prone communities are likely to have been severely affected by the pandemic, even though the real impact, in terms of human and animal rabies deaths, of this 3-year-long health crisis may remain unknown. This is because rabies surveillance, already weak before the pandemic, collapsed during it, mainly due to restrictions on the movement of the field surveillance staff that led to cases being missed or investigated late (Raynor *et al.*, 2021; Nadal *et al.*, 2022a). Moreover, a vicious cycle was observed: access to and delivery of PEP declined, so fewer dog-bite cases were reported, bite reports were not sent to investigators and incidents remained unaddressed.

Access to PEP was impacted by the pandemic in most countries because people were worried about COVID-19 infections at hospitals and were unable to reach them due to reduced public transportation and reluctance to share private transportation. PEP delivery was disrupted too, due to a shortage of human vaccines (because of supply issues and financial constraints) and staff shortages (because of quarantine, illness or redeployment) (Gongal *et al.*, 2022; Nadal *et al.*, 2022a). In a war-torn, endemic country, where human vaccines have usually been available in private clinics, none could be found during the first year of the pandemic. The postponement of the vaccine investment strategy for rabies by Gavi, the Vaccine Alliance, has been a major concern for under-resourced countries.

Awareness activities for children, usually carried out at schools, survived the beginning of the pandemic only in very few countries. Online events, both for at-home children and the larger community, were able to reach only those who could afford a computer at home and a good Internet connection (Nadal *et al.*, 2022a).

Yet the most severely disrupted element of the rabies elimination strategy was mass dog vaccination (Raynor *et al.*, 2021; Nadal *et al.*, 2022a). Disruptions included delays of at least 6 months, prolonged duration of vaccination campaigns (when performed), increased costs and failure to reach targets. The main hindrances were the restrictions on the movement of dog vaccinators and the struggle to organize vaccination campaigns that adhered to COVID-19 safety guidelines (especially where the campaigns are usually carried out by non-governmental organizations rather than the government).

Overall, in the endemic countries that were just beginning their journey to the Zero by 30 goal, 'the momentum that was gaining was lost', while the countries that were progressing towards it well experienced an unfortunate step back. Additionally, the pandemic has shown once more the global inequity in vaccine access. This is a well-known problem in the case of rabies, where effective vaccines, tools and strategies are there, but they fail to reach those who most need them. That said, the past 3 years could have had a potentially positive effect in the long term, in terms of: (i) an improved cold chain; (ii) strengthened diagnostic capacity; (iii) increased regional coordination; and (iv) augmented awareness about the importance of safeguarding animal health and the key role of the veterinary sector.

1.8 2030 and Beyond

Looking at the future, the main lessons learnt during the pandemic can be summarized as follows (Nadal *et al.*, 2022a):

- It is crucial to mobilize long-term political commitment and sufficient and sustainable financial, infrastructural and workforce-related resources to catch up on the delay accumulated during the pandemic and advance fast in phases 1 and 2 of the Zero by 30 plan.
- Efforts should be directed to the support of the animal health sector, in particular, to make sure that mass dog vaccination becomes a consolidated rabies control strategy in all rabies-endemic countries.
- A rabies-dedicated budget should be created to ensure the stable procurement of human and animal vaccines, which should be considered essential biologicals even in times of crisis.
- It is vital to identify the most cost-effective and sustainable methods of meeting the needs of local communities, to facilitate the access and delivery of PEP and dog vaccination.
- A simple but effective and sustainable participatory disease surveillance mechanism should be developed, for human and animal healthcare professionals to quickly receive information about dog bites and rabies cases directly from local communities.
- A well-rounded rabies communication strategy should be designed to target both children and adults, using the channels and tools that people can easily access in normal times and especially during crises.

Authors' Declaration

All authors declare that they have no conflict of interest.

All authors have approved this manuscript, agree with its submission, and share collective responsibility and accountability.

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