29 One Health in Policy Development: Options to Prevent Rabies in Cattle in Bhutan

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Introduction

Bhutan is a small, landlocked Himalayan kingdom located in South Asia, between China to the north and India to the south, west and east. About 60% of its population (estimated at 750,000) live in rural areas and depend on agriculture and livestock farming for their livelihoods. As a result, livestock remains critical to enhancing and sustaining rural livelihoods. With the country's aim to attain self-sufficiency in livestock products, the Royal Government of Bhutan prioritized improvement of livestock productivity, including dairy cattle. Besides ensuring accessibility to breed improvement programmes by establishing artificial insemination centres and supplying breeding bulls across the country, the government also provides subsidies to import exotic breeds of cattle, mostly from India, to supplement the supply of improved cattle breeds within Bhutan. Because of this, the number of farmers rearing exotic breeds of dairy cattle, mainly European breeds such as Jersey, have been increasing. For instance, the percentage of imported cattle breeds increased from 24.1% in 2012 to 27.4% in 2014 while the indigenous cattle (*Bos indicus*) decreased from 75.9% in 2012 to 72.6% in 2014 (MoAF, 2015). As rural communities are dependent on cattle and other livestock species for their livelihoods, infectious diseases such as rabies, brucellosis, anthrax and leptospirosis not only reduce productivity and result in death of animals, but also pose a significant public health risk. Whereas all livestock diseases have a potential impact on rural communities, some have more immediate impacts. Rabies, due to the high case fatality rate in exposed individuals and the potential public health risk, remains a disease of great concern. Although dog-mediated rabies has been successfully eliminated from most regions of Bhutan, it remains endemic in the southern parts of the country (Tenzin *et al*., 2012a). Sporadic incursions are also reported in the east (Tenzin *et al*., 2017). Elimination of rabies from the southern part of Bhutan is complicated by the porous border with the neighbouring Indian states of West Bengal and Assam. Dogs are the main reservoir for rabies in Bhutan and it is thought that wildlife-transmitted rabies is currently not a significant consideration in the region. Further work may be needed to fully assess this in the future. Around 17 outbreaks of rabies are reported annually in dogs with spillover infection to other domestic animals, resulting in continuous public health risks and economic losses (NCAH, 2017). There has not been a human case of rabies reported in the country since 2016.

Statistics from the National Centre for Animal Health (NCAH) indicate that cattle are the most frequently affected livestock in the rabies endemic areas of Bhutan. In 366 outbreaks reported between

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1996 and 2017, the most frequently reported were in cattle (51%), followed by dogs (41%), cats (2%), horses (1.7%), goats (1.6%), pigs (1.4%) and sheep (0.2%) (Tenzin *et al*., 2019). Rabies cases in dairy cattle potentially lead to claims of mass exposure in humans, largely due to consumption of products from rabies-suspected cattle (CDC, 1999; Tenzin *et al*., 2010b). Requests from the public for post-exposure prophylaxis (PEP), related to potential exposure to rabid cattle or their products, may occur where there is delayed identification and reporting of cattle cases due to the lack of knowledge about the clinical signs in cattle and uncertainty about transmission risk. Annually it is estimated that around 10% of people receiving PEP for rabies in Bhutan are subsequent to consumption of meat and dairy products derived from cattle confirmed to have died of rabies (Tenzin *et al*., 2012b). The Royal Government of Bhutan currently spends an average of 9 million Bhutanese Ngultrum (BTN) (US$142,000) annually to provide PEP to potentially exposed individuals (Penjor *et al*., 2019). In the National Rabies Prevention and Control Plan, it is recommended that cattle demonstrating signs of rabies should be quarantined, euthanized and subsequently tested (NCAH, 2017). As Bhutan is predominantly a Buddhist country, pre-emptive culling of exposed cattle based on risk assessment is a difficult option to undertake, although cattle can be quarantined until death occurs naturally. If cattle have a history of being bitten by a rabid dog, and clinical signs have not developed, the current control plan recommends that the veterinarian undertake post-exposure prophylactic treatment in cattle (NCAH, 2017).

The current government rabies control policy facilitates the implementation of an effective and coordinated rabies control programme in the dog population. As a result, there is currently no general directive for broad implementation of pre-exposure vaccination for rabies in cattle (Rinchen, 2018). This chapter describes the complex issue of handling rabies cases in cattle in Bhutan and illustrates the value of taking a cross-sectoral One Health approach to developing policy options.

One Health in Bhutan

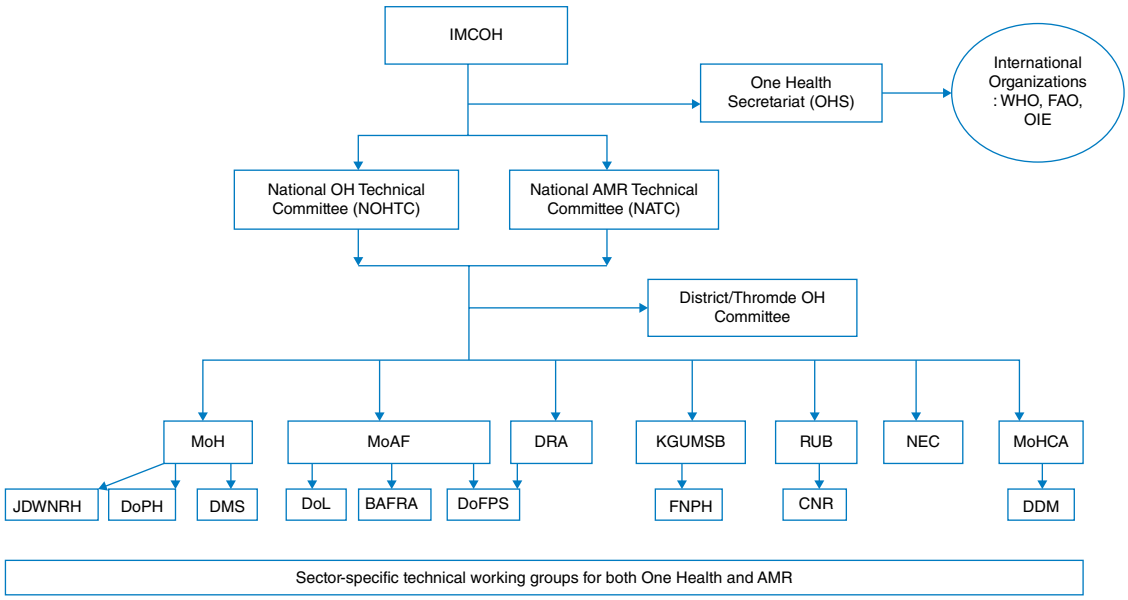
Globally, there is growing acceptance that taking an interdisciplinary cross-sectoral approach is essential if we want to address the complexity of emerging human, animal and environmental health problems (Zinsstag *et al*., 2012; Cork *et al*., 2016). While the concept of 'One Health' has recently gained momentum at the global level, in Bhutan there has long been a well-integrated and coordinated mechanism for prevention and control of zoonotic diseases. This was further strengthened during the outbreak of highly pathogenic avian influenza (HPAI) in 2003 in South-east Asia. At this time, the Department of Public Health (DoPH) under the Ministry of Health (MoH) and the Department of Livestock (DoL) and Bhutan Agriculture and Food Regulatory Authority (BAFRA) under the Ministry of Agriculture and Forests (MoAF), collaborated to carry out a joint risk assessment. This was followed by successful delivery of a World Bank-funded National Influenza Preparedness and Response Project and development of the National Influenza Pandemic Preparedness Plan (NIPPP). Implementation of the NIPPP led to rapid containment of 13 HPAI outbreaks in poultry, with the first outbreak in February 2010 effectively controlled using a One Health approach. The MoAF (DoL and BAFRA) and MoH (DoPH) subsequently collaborated on development of further guidelines and plans for prevention and control of zoonotic diseases such as rabies, anthrax and scrub typhus (McKenzie *et al*., 2016). Currently, a One Health approach is used to investigate and respond to any outbreak of zoonotic disease in Bhutan (see Table 29.1).

Two ministries (MoAF and MoH) collaborated on the development of the Bhutan One Health Strategic Plan (2017–2021) which was formally approved by the government in 2017 (MoAF and MoH, 2017). Subsequently a memorandum of understanding was signed between MoAF, MoH and other collaborating partners, including the National Environment Commission (NEC), the Ministry of Home and Cultural Affairs and academic institutions (Royal University of Bhutan and Khesar Gyalpo University of Medical Sciences of Bhutan), in November 2017 on the eve of World One Health Day. A proposal for formal establishment of a One Health Secretariat is currently being pursued in the country (Fig. 29.1). This will probably be based at the Royal Centre for Disease Control (RCDC) near to the capital city Thimphu.

The MoAF and MoH also collaborated on the launch of a series of national One Health conferences to sensitize human and animal health personnel, and other stakeholders, to the concept of One Health and promote multisectoral coordination

Table 29.1. Guidelines and disease prevention and control plan documents for zoonotic diseases jointly developed by Ministry of Agriculture and Forests (MoAF) and Ministry of Health (MoH).

Name of guideline or disease prevention and control plan	Year
National Influenza Pandemic Preparedness Plan for Human Health Sector	2009
Guidelines for Preparedness, Surveillance and Control of Anthrax in Human and Animals in Bhutan	2013
National Guidelines for Management of Rabies and Anti-rabies Prophylaxis in Bhutan	2014
National Influenza Pandemic Preparedness Plan for Animal Health Sector	2014
National Rabies Prevention and Control Plan	2017
Bhutan One Health Strategic Plan 2017–2021	2017
Strategic Plan for Elimination of Dog-mediated Human Rabies in Bhutan by 2030	2019



IMCOH: Inter-Ministerial Committee for One Health
MoH: Ministry of Health
JDWNRH: Jigme Dorji Wangchuck National Referral Hospital
DoPH: Department of Public Health
DMS: Department of Medical Services
MoAF: Ministry of Agriculture and Forests
BAFRA: Bhutan Agriculture and Food Regulatory Authority
DoFPS: Department of Forest and Park Services
DoI: Department of Livestock
DRA: Drug Regulatory Authority
KGUMSB: Khesar Gyalpo University of Medical Sciences of Bhutan
FNPH: Faculty of Nursing and Public Health
RUB: Royal University of Bhutan
CNR: College of Natural Resources
NEC: National Environment Commission
MoHCA: Ministry of Home and Cultural Affairs
DDM: Department of Disaster Management

Fig. 29.1. Institutional arrangement for One Health in Bhutan. AMR, antimicrobial resistance; FAO, Food and Agriculture Organization of the United Nations; OH, One Health; OIE, World Organisation for Animal Health; WHO, World Health Organization.

and collaboration at the national, regional and district level.

Other recent initiatives include a European Union (EU)-funded One Health training programme. As part of this, six human and animal health professionals from Bhutan were given the opportunity to pursue master's studies in collaboration with Massey University, New Zealand. The programme facilitated several collaborative One Health research projects in Bhutan and neighbouring countries (McKenzie *et al.*, 2016). The two ministries were also successful in acquiring a

Fleming Fund Country Grant on Antimicrobial Resistance (AMR) from the UK Government, Department of Health and Social Care. This project is expected to improve surveillance for AMR in both the human and the animal health sectors. In addition to the country grant, the Fleming Fund also awarded seven fellowships to provide continuing professional development and leadership training opportunities.

Research to Inform Policy

Bhutan has proactively supported several collaborative research projects to inform the development of the National Rabies Prevention and Control Plan. Several studies have been conducted on the epidemiology of dog-mediated rabies in Bhutan, assessment of the economic impact, molecular characterization of virus isolates, and an assessment of community knowledge, attitude and practice associated with the control of rabies in dogs (Tenzin *et al*., 2019). These studies have built on, and complement, work done in other countries (Zinsstag *et al*., 2009, 2017). However, despite cattle being the most frequently infected livestock species, no study had previously been conducted to explore options to prevent rabies in cattle or mitigate the associated economic losses and public health risks (Rinchen, 2018).

Currently, a common problem faced by human health physicians in Bhutan is to rationalize use of PEP. There may be pressure to provide PEP even where the risk of exposure to live virus is likely to have been very low. For example, PEP may be demanded by a large number of people with a history of drinking the milk from or handling or dressing cattle subsequently found to have died of rabies. During such occasions, especially where there is uncertainty about the likelihood of exposure, a large number of people may be provided with PEP, and the subsequent cost to the government is substantial. To date, there has not been a significant shortage of PEP available to physicians in Bhutanese health clinics, but this might not always be the case. It is recognized that allocation of scarce resources would need to be determined using case-by-case risk assessment. As a result, a key area of research identified was to better assess the public health risks associated with exposure to rabid cattle or following consumption of products derived from presumptive rabid cattle.

While the risk associated with consuming well-cooked meat and pasteurized milk is considered to be negligible, transmission of rabies from consuming raw meat and milk remains theoretically possible (CDC, 1999). It is reported that dressing the carcasses of animals that have died of rabies and handling rabid animals, including cattle, can potentially be a source of infection in humans. For example, Wertheim *et al*. (2009) reported two separate cases of human rabies after butchering, processing and consuming a suspected rabid dog and cat in Vietnam. It is, however, not clear if the infection occurred from the oral route or due to contact between infectious fluids with damaged mucous membranes or abraded skin while dressing the carcass. Similarly, Tariq *et al*. (1991) reported a case of rabies in a butcher who died after skinning a calf that had previously expressed neurological signs. Cases of rabies in animal health workers and animal owners following handling of rabid animals have been reported from Brazil and Iran (Brito *et al*., 2011; Simani *et al*., 2012). In a review of non-bite rabies transmission, Afshar (1979) reported rabies transmitted to a lamb nursed by an experimentally infected ewe. It is possible for the virus to access mammary tissue and subsequently to be excreted in the milk. A study carried out in India demonstrated presence of viral RNA in the milk of rabies-suspected cows (Dandale *et al*., 2014). The World Health Organization (WHO) states that drinking raw milk from a rabid animal, although not advised, does not result in exposure to rabies virus and thus PEP is not advised (WHO, 2018). However, in rabies endemic countries where rabies is highly prevalent, low-risk exposures associated with rabies in cattle often place physicians under pressure, especially where community members demand PEP. It is clear that, in addition to considering the technical aspects of rabies prevention and control, it is also important to understand the cultural perspectives, the level of understanding and behaviour of community members because lack of public engagement in the development and delivery of disease control programmes is frequently a key barrier to success. Further research on this aspect is required (Rinchen *et al*., 2019).

Current Government Policy for Rabies

Government policy for rabies control in Bhutan currently encourages a One Health approach, as described later in this chapter. Key factors for

considering and evaluating the One Health approach are described by Zinsstag *et al*. (2015a,b,c) (see also Zinsstag *et al*., Chapter 2; Schelling and Hattendorf, Chapter 8; Häsler *et al*., Chapter 10; Zinsstag *et al*., Chapter 31, all in this volume). Rabies is a notifiable disease for both human and animal health sectors in Bhutan. The DoL currently oversees the rabies control activities in the country. Management of zoonotic diseases, including rabies, is listed in both the Livestock Act of Bhutan 2001 and the Livestock Rules and Regulation 2017. The National Rabies Prevention and Control Plan (NCAH, 2017) specifies the detailed plan of action including the roles and responsibilities of various stakeholders for prevention and control of rabies. Rabies prevention and control in the country is also emphasized in the National Dog Population Management Strategy (MoAF, 2019) and Bhutan One Health Strategic Plan 2017–2021. The Human Rabies Management Guideline 2014 covers aspects of dog bite management, rabies case management, reporting for surveillance and standard recommendations for rabies PEP in humans. Recent assessment of rabies control using the 'Stepwise Approach towards Rabies Elimination' (SARE) tool was done in September 2017 and May 2019, revealing a score of 3.5/5 indicating that rabies in animals is under control and the country is gearing towards an elimination phase (Fig. 29.2). Based on this assessment, Bhutan developed a Strategic Plan for Elimination of Dog-mediated Human Rabies by 2030 (MoAF and MoH, 2019).

Bhutan is the first country in Asia that has committed to the 'United Against Rabies' collaboration (a collaboration between the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE), WHO and the Global Alliance for Rabies Control (GARC)) to eliminate dog-mediated rabies by 2030 (WHO, OIE, FAO and GARC, 2018). Under the zero by 30 global strategy plan, there are Start up (2018–2020), Scale up (2021–2025) and Mop up (2026–2030) phases of the rabies elimination plan. Bhutan is included in the Start up phase as one of 29 countries to demonstrate successful elimination of rabies. Aligning the current rabies control programme to the goal of zero by 30, the government emphasizes mass dog vaccination, awareness education, and availability and accessibility of PEP to humans exposed to potential rabid animals.

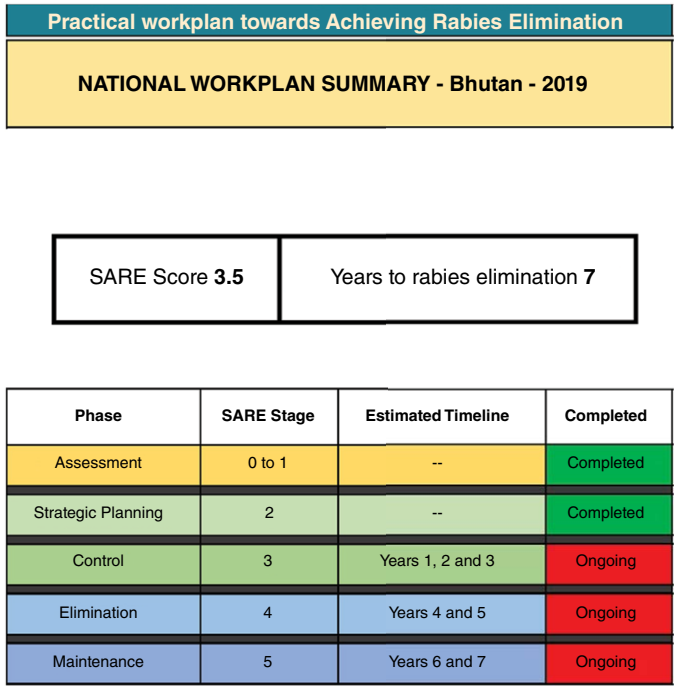


Fig. 29.2. Stepwise Approach towards Rabies Elimination (SARE) assessment score for Bhutan.

Control of rabies in dogs

Dogs are the primary reservoir of rabies in Bhutan, and there is a large population of free-roaming and stray dogs which travel freely across the southern border. Cross-border transmission of rabies poses an ongoing risk of the virus spreading into interior rabies-free areas of the country due to the large size of the dog population. In 2016, Bhutan had a total dog population of 119,624 (71,245 owned dogs and 48,379 free-roaming dogs) (Rinzin *et al.*, 2016). Since mass dog vaccination is a cost-effective and proven tool for elimination of canine rabies virus, the current government policy aims to achieve > 70% vaccination coverage supported by dog population management through a programme called Catch-Neuter-Vaccinate-Release (CNVR). The government procures canine rabies vaccine and occasionally has supplies donated by the OIE through OIE Vaccine Bank.

As part of the Animal Birth Control programme, free-roaming dogs are caught on the street by trained dog catchers and taken to clinics where they are neutered and vaccinated against rabies. Between 2009 and 2019, about 105,000 dogs and cats were neutered and vaccinated against rabies under the CNVR programme (Tshedup, 2020). Annual mass dog vaccination campaigns are routinely carried out to create an immune buffer along the southern border. In addition, owned dogs are vaccinated annually on World Rabies Day (28 September) or when presented at animal health centres located across the country. In some areas, the vaccination coverage is low (about 30%) due to logistical challenges to catch and vaccinate large numbers of free-roaming dogs. It was estimated that 57% vaccination coverage had previously been achieved in two rabies endemic towns in southern Bhutan (Tenzin *et al.* 2015).

Rabies education

Awareness education on rabies is crucial to ensure that the public are aware about the disease, its public health implications and available risk mitigation options. Further, as the public play a critical role in any disease control programme, awareness campaigns are important in garnering community support to implement effective disease control activities. Currently, information on rabies is disseminated in several ways. At the sub-district level, livestock extension officers conduct training programmes in which awareness on rabies is imparted to communities (Fig. 29.3). Every year on the 28 September, coinciding with the World Rabies Day, awareness education is disseminated to a diverse target group through road shows, walkathons, and rabies talk and quiz programmes in schools. Further, in collaboration with the Bhutan Broadcasting Service (BBS), radio programmes and rabies videos are broadcast to disseminate information on rabies and other zoonotic diseases. In a recent study conducted among 562 cattle owners in the selected rabies endemic and rabies non-endemic areas of Bhutan, the most reported source of rabies information was neighbours (315), followed by formal news media (122), animal health training programmes and rabies awareness campaigns (113), family members (58), schoolchildren (45) and the Internet (8) (Rinchen *et al.*, 2019).

Early reporting and rapid response

Use of smartphone and social media apps played an important role in ensuring timely reporting of rabies and other disease outbreaks in Bhutan. Suspected cases of rabies and other notifiable diseases are mostly reported by community members to the nearest animal health centres. Upon a preliminary investigation, the suspected outbreak is reported to the district, regional and national level through use of a flash reporting system, e-mail and phone call. The flash reporting form is a one-page form that contains the details of the outbreak, such as species and number of cases, owner's name, farm or place name, date of outbreak, suspected source, number and population at risk and the intervention measures undertaken at the local level. Once an outbreak is confirmed, a rapid response team, comprised of members from the DoL, DoPH, BAFRA and other relevant stakeholders, is formed to contain the outbreak (NCAH, 2017). However, challenges regarding effective response to rabies outbreaks remain, largely due to limited resources – both financial and human resources – and the difficult terrain of the country.

Change of the rabies PEP protocol in humans

The production and use of nerve tissue vaccine (NTV) was phased out in all South Asian countries. Bhutan discontinued use of NTV in 1996 and replaced it with human diploid cell culture vaccine.

Fig. 29.3. Rabies awareness education programme conducted in a rabies endemic area of Bhutan.

In 2013, the country introduced the lower cost but equally effective updated Thai-Red Cross intradermal rabies vaccine regimen. The MoH is in the process of further updating the PEP regimen that requires the patient to visit a clinic only three times and complete the course in 1 week (WHO, 2018).

Rabies prevention in cattle

In Bhutan, vaccines for most livestock diseases are provided free of cost by the government. However, cattle and other livestock species are not routinely vaccinated against rabies, as there is no government policy supporting pre-exposure vaccination. The current rabies control programmes in Bhutan are focused on mass dog vaccination that requires at least 70% coverage of the dog population to interrupt transmission among dogs (Coleman and Dye, 1996). However, endemic areas in Bhutan are faced with ongoing cross-border transmission associated with the movement of free-roaming rabid dogs.

The OIE recommends vaccinating cattle and other livestock species in rabies endemic areas (OIE, 2020). A preliminary economic analysis indicated the benefit of vaccinating cattle in the high-risk areas within the rabies endemic areas of the country (Rinchen, 2018). This should be supplemented with improved management practices such as proper housing of animals, enhanced monitoring during rabies outbreaks, rapid containment of outbreaks, and further awareness education on rabies for cattle owners (Rinchen *et al*., 2019). However, a more comprehensive study including further assessment of the economic benefits of the pre-exposure vaccination in cattle is required to make a sound policy decision.

Post-exposure treatment options in cattle

Post-exposure treatment is provided to domestic animals including cattle following exposure to a suspected rabid dog bite injury. However, this requires early detection of bite incidents, identification of the bite wound, immediate first-aid measures including thorough washing of the bite wound with soap and water followed by appropriately administered PEP (NCAH, 2017). It is reported that early detection and prompt treatment has saved several animals during rabies outbreaks in eastern Bhutan. The current Essen regimen practice of administering 1 ml of rabies vaccine intramuscularly on days 0, 3, 7, 14 and 28 may be replaced with the modified Essen regimen of administering 3 ml, 3 ml, 2 ml, 1 ml, 1 ml on days 0, 3, 7, 14 and 28,

respectively. Using this modified Essen regimen resulted in high protective virus neutralizing antibody titres of 1.243 IU/ml, 8.905 IU/ml, 27.5 IU/ml and 52.5 IU/ml on days 3, 7, 14, 28 post-vaccination, respectively, and elicited higher antibody level when compared with the standard Essen regimen in cattle (Abraham, 2019). PEP in animals is also practised in other countries (Manickama *et al*., 2008; Wilson, 2010).

Cross-border harmonization

Except for islands and countries surrounded by difficult geographical features (e.g. the rugged terrain of the Himalayas) cross-border transmission of disease remains an ongoing challenge. Any country that shares a contiguous and porous land border with a rabies endemic country is constantly facing risk of new incursions (Gongal and Wright, 2011). One of the major challenges in Bhutan's effort towards elimination of rabies from its territory is the transboundary transmission of rabies associated with cross-border movement of free-roaming dogs between rabies endemic areas of Bhutan and neighbouring states in India. A need for regional cooperation in implementing parallel disease control programmes among the regional member states has been emphasized at various regional meetings (Gongal and Wright, 2011).

Challenges to Rabies Control

Bhutan aims to achieve zero dog-mediated human rabies deaths by 2030. However, there are several challenges that the country must overcome in achieving this goal (MoAF and MoH, 2019).

Rabies diagnostics

Having an adequate and reliable diagnostic capacity to detect and confirm cases of rabies is an important component of an effective rabies control plan. This remains a constraint in many rabies endemic and resource-poor settings. Bhutan currently has a robust rabies surveillance programme and good access to diagnostic services which are provided through a network of veterinary staff and veterinary laboratories. Laboratories at the district and regional level have the screening capacity to test for rabies using rapid diagnostic test kits while the confirmatory diagnosis of rabies, using the gold standard fluorescence antibody test (FAT), is done at the NCAH near Thimphu (Tenzin *et al*., 2020). The FAT was also established in one regional laboratory in the eastern part of the country. Previously, having to send all suspect samples for confirmation to NCAH increased the turnaround time and therefore the risk of disease spread and human cases. Further development of the veterinary diagnostic system is likely to be considered as more advanced technology becomes available. Although the current system is functional, there remain logistical challenges and constraints with regard to financial and human resources.

Uncertainties around providing PEP in self-reported atypical exposures

In Bhutan, PEP is provided free of cost to exposed individuals. As outlined earlier in this chapter, the cost to the public health sector further escalates when PEP is provided to 'mass exposure' cases. The level of PEP provided by the human health sector is determined by the category of bite wound (category I, II and III). The highest-risk category (III) is also provided with hyper-immune serum, as recommended in the current WHO guidelines (WHO, 2018). Whereas the guidelines for handling cases of dog bites are well established, the approach to dealing with cases of atypical exposure to rabies is less clear, especially where there remains a level of uncertainty around risk. Decisions depend on a number of factors including the clinical discretion of the human health practitioner.

Porous border

Currently, only the areas that share a border with the neighbouring states of India regularly report rabies (Fig. 29.4). Whereas there are regulations regarding the cross-border movement of livestock, it is difficult to regulate movement of free-roaming dogs in these areas. Recognizing the value of vaccinating dogs on both sides of the border, the DoL has undertaken targeted sterilization and vaccination of dogs on the other side of the border. However, Bhutan is a resource-limited country and funding activities to undertake rabies control across the border is not a sustainable approach. Currently through cross-border harmonization meetings at the local level, a platform is being created to share ideas and resources to deal with the complex problem of transboundary animal diseases in the region. There is an urgent need to develop a sustainable mechanism for cross-border rabies control activities on both sides of the border.

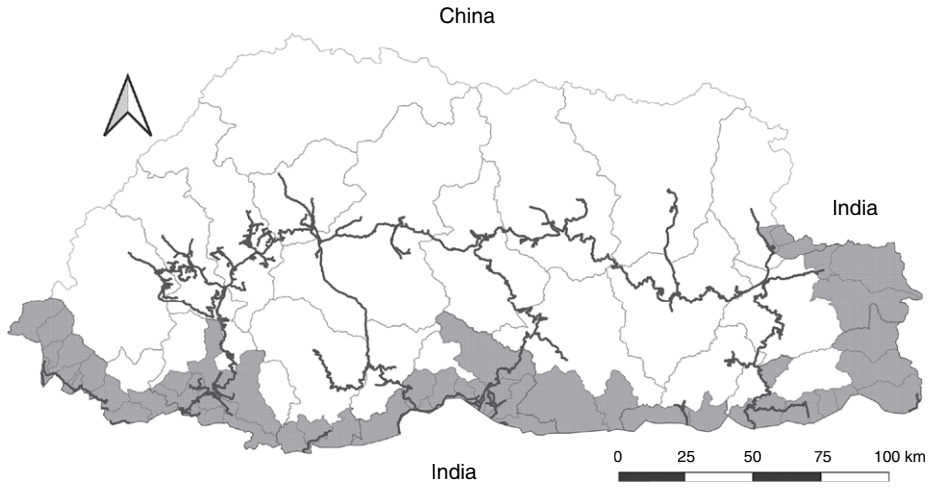


Fig. 29.4. Rabies endemic areas of Bhutan (shaded areas in the map) and the four national highways (black lines) connecting rabies endemic and non-endemic areas.

Increasing free-roaming dog population

Dogs are an integral part of the Bhutanese culture and are widely accepted in Bhutanese communities. They live closely with the people and feed on kitchen waste and leftovers. These factors facilitate breeding and contribute to the growing free-roaming dog population. Other sources of free-roaming dogs include owned dogs allowed to roam freely and owned dogs that are abandoned by their owners. A study found that about 16% of free-roaming dogs were actually owned in two southern Bhutanese border towns, Phuentsholing and Gelephu (Rinzin *et al*., 2016). The unique and complex relationship between the dogs and communities in Bhutan contributes to the growing free-roaming dog population and also poses a potential risk for the spread of rabies. The DoL, with support from relevant stakeholders, continues to implement the CNVR model to control the free-roaming dog population but this is a resource-intensive exercise. It is recognized that there needs to be broader collaboration among various stakeholders to ensure proper waste management and responsible pet ownership.

In view of ensuring effective management of the dog population in the country, the National Dog Population Management (DPM) Strategy was recently launched (MoAF, 2019). The strategy will reinforce the DPM programme at the national, district, municipal and sub-district levels, and ensure effective collaboration between the relevant stakeholders.

Current cattle-management practices

Vaccination of cattle against rabies was discussed above. Additionally, exposure risks can be reduced by minimizing contact between cattle and free-roaming dogs, by reducing free grazing, fencing pasture land and providing proper animal housing. However, in a study conducted by Rinchen *et al*. (2019), about 70% of cattle owners (n = 562) reported having only a temporary shed or no shed for their cattle while the majority of them (86%) reported practising extensive or semi-extensive grazing, where cattle are freely grazed with little monitoring. Although there are financial incentives (e.g. access to building materials for shed construction) to change cattle-rearing practices on the outskirts of larger towns (Wangchuk *et al*., 2014), deep-rooted farming practices of free-grazing cattle, compounded by a farm labour shortage, will continue to pose challenges in bringing positive change in cattle-management practices.

Risk of rabies introduction into rabies-free areas

The western, central and northern regions of Bhutan have not reported any rabies outbreaks for almost two decades. However, the trend towards increasing human settlement along highways in Bhutan connects rabies endemic and rabies-free areas and facilitates overlap of dog home ranges. The latter enables interaction of free-roaming dogs

and may provide an ideal environment for sustained dog-to-dog transmission of rabies and expansion into non-endemic areas (Rinchen *et al*., 2020). Rabies incursion into the rabies-free areas of Bhutan, resulting from distant movement of rabid dogs, has been reported in the past (Tenzin *et al*., 2010a,b). In these outbreaks, dog-to-dog transmission along the road networks is believed to have sustained the spread of rabies. Similar instances of dog-mediated rabies spreading along highways and human dwelling areas is reported elsewhere (Waltner-Toews *et al*., 1990; Bamaiyi, 2015). Therefore, it is vital to extend dog vaccination programmes into areas adjacent to the rabies endemic areas to prevent infection and spread in the susceptible dog population.

In addition, rabies can be introduced through human-mediated movement of pet animals. For example, recently a case of rabies in a dog imported from India was reported from Haa, a town in the non-endemic north-western region of Bhutan (Tenzin, 2016). Although the Livestock Rules and Regulation of Bhutan 2017 stipulates a valid permit for import and movement of pets within the country, outbreak investigation revealed that the pet owner was not aware of the import permit requirements. This incident underlines the need to sensitize animal/pet owners about the existing rules and regulations regarding animal movement and their importance to achieving maximum compliance. Further, the risk of rabies reintroduction into a rabies low-risk zone through pet animals can be mitigated by enhancing inspection for illegal movement of pets at the check posts along highways. Several incidences of human-mediated translocation of rabid dogs from rabies endemic areas to canine rabies-free countries have been reported (Castrodale *et al*., 2008; Ribadeau-Dumas *et al*., 2016). Given the global move towards zero by 30, reintroduction of rabies into rabies-free territories would be a huge setback and thus remains a significant concern.

Conclusion

By taking a One Health approach, the Government of Bhutan established a leading role in tackling emerging infectious diseases in humans and animals in the region. As a result, Bhutan has successfully eliminated rabies from most parts of the country. This was achieved through sustained mass dog vaccination, backed by strong policy support, and effective community education programmes. Bhutan was the first country in Asia to commit to the 'United Against Rabies' goal to eliminate dog-mediated human rabies by 2030 (WHO, OIE, FAO and GARC, 2018), and current control programmes have been aligned to achieve this target. In developing effective rabies control plans, Bhutan also faces the challenge of responding to rabies infection in cattle and other livestock species. Ultimately, this will depend on elimination of rabies in the dog population. Achieving rabies control in cattle is challenged by free unregulated movement of dogs across the porous border especially in the south and parts of eastern Bhutan. At the present time, enhanced control of rabies in cattle could be achieved by targeted vaccination of cattle in the high-risk areas of the country as well as enhanced farmer education, changes in cattle management and less extensive grazing during rabies outbreaks. However, in view of the increasing number of rabies cases reported in cattle, and the important role that cattle play in sustaining rural livelihoods, there is a need to continue efforts to control rabies in dogs with a concurrent effort to improve livestock management.

References

Abraham, S.S. (2019) Modified Essen regimen for post exposure rabies prophylaxis in cattle, a novel approach for control of rabies in cattle. *East African Scholars Journal of Veterinary Medical Science* 1(5), 54–57.

Afshar, A. (1979) A review of non-bite transmission of rabies virus infection. *British Veterinary Journal* 135(2), 142–148.

Bamaiyi, P.H. (2015) 2015 Outbreak of canine rabies in Malaysia: review, analysis and perspectives. *Journal of Veterinary Advances* 5(12), 1181–1190.

Brito, M.G., Chamone, T.L., da Silva, F.J., Wada, M.Y., Miranda, A.B. *et al*. (2011) Antemortem diagnosis of human rabies in a veterinarian infected when handling a herbivore in Minas Gerais, Brazil. *Revista do Instituto de Medicina Tropical de São Paulo* 53, 39–44.

Castrodale, L., Walker, V., Baldwin, J., Hofmann, J. and Hanlon, C. (2008) Rabies in a puppy imported from India to the USA, March 2007. *Zoonoses and Public Health* 55(8–10), 427–430.

CDC (1999) Mass Treatment of Humans Who Drank Unpasteurized Milk from Rabid Cows – Massachusetts, 1996–1998. Centers for Disease Control and Prevention, Atlanta, Georgia. Available at: https://www.cdc.gov/mmwr/preview/mmwrhtml/00056759.htm (accessed 18 June 2020).

Coleman, P.G. and Dye, C. (1996) Immunization coverage required to prevent outbreaks of dog rabies. *Vaccine* 14(3), 185–186.

Cork, S.C., Hall, D.C. and Lijebjelke, K.A. (2016) *One Health Case Studies: Addressing Complex Problems in a Changing World*. 5M Publishing, Sheffield, UK.

Dandale, M., Singh, C., Sandhu, B., Bansal, K. and Sood, N. (2014). Intravitam diagnosis of rabies from milk: comparison of nested RT-PCR with TaqMan real time PCR. *IOSR Journal of Agriculture and Veterinary Science* 1(1), 4.

Gongal, G. and Wright, A.E. (2011) Human rabies in the WHO Southeast Asia Region: forward steps for elimination. *Advances in Preventive Medicine* 2011, 383870.

Manickama, R., Basheer, M.D. and Jayakumar, R. (2008) Post-exposure prophylaxis (PEP) of rabies-infected Indian street dogs. *Vaccine* 26(51), 6564–6568.

McKenzie, J.S., Dahal, R., Kakkar, M., Debnath, N., Rahman, M. *et al*. (2016) One Health research and training and government support for One Health in South Asia. *Infection Ecology and Epidemiology* 6, 33842.

MoAF (2015) Bhutan RNR Statistics 2015. Ministry of Agriculture and Forests, Thimphu. Available at: http://www.moaf.gov.bt/bhutan-rnr-statistics-2015/ (accessed 1 January 2020).

MoAF (2019) National Dog Population Management Strategy launched. Ministry of Agriculture and Forests, Thimphu. Available at: http://www.moaf.gov.bt/national-dog-population-management-strategy-launched/ (accessed 5 July 2019).

MoAF and MoH (2017) Bhutan One Health Strategic Plan (2017–2021). Ministry of Agriculture and Forests and Ministry of Health, Thimphu.

MoAF and MoH (2019) Strategic Plan for Elimination of Dog-mediated Human Rabies in Bhutan by 2030. Ministry of Agriculture and Forests and Ministry of Health, Thimphu.

NCAH (2017) National Rabies Prevention and Control Plan. National Centre for Animal Health, Department of Livestock, Thimphu.

OIE (2020) Technical Disease Cards. World Organisation for Animal Health, Paris. Available at: https://www.oie.int/animal-health-in-the-world/technical-disease-cards/ (accessed 5 July 2019).

Penjor, K., Tenzin, T. and Jamtsho, R.K. (2019) Determinants of health seeking behavior of animal bite victims in rabies endemic South Bhutan: a community-based contact-tracing survey. *BMC Public Health* 19(1), 237.

Ribadeau-Dumas, F., Cliquet, F., Gautret, P., Robardet, E., Le Pen, C. and Bourhy, H. (2016) Travel-associated rabies in pets and residual rabies risk, Western Europe. *Emerging Infectious Diseases* 22(7), 1268–1271.

Rinchen, S. (2018) Options to prevent rabies in cattle in Bhutan. MSc. thesis, University of Calgary, Calgary, Alberta, Canada. Available at: https://prism.ucalgary.ca/handle/1880/106433 (accessed 5 July 2019).

Rinchen, S., Tenzin, T., Hall, D., van der Meer, F., Sharma, B. *et al*. (2019) A community-based knowledge, attitude, and practice survey on rabies among cattle owners in selected areas of Bhutan. *PLoS Neglected Tropical Diseases* 13(4): e0007305.

Rinchen, S., Tenzin, T., Hall, D., and Cork, S. (2020) A Qualitative Risk Assessment of Rabies Reintroduction Into the Rabies Low-Risk Zone of Bhutan. *Frontiers in Veterinary Science* 7, 366. doi: 10.3389/fvets.

Rinzin, K., Tenzin, T. and Robertson, I. (2016) Size and demography pattern of the domestic dog population in Bhutan: implications for dog population management and disease control. *Preventive Veterinary Medicine* 126, 39–47.

Simani, S., Fayaz, A., Rahimi, P., Eslami, N., Howeizi, N. and Biglari, P. (2012) Six fatal cases of classical rabies virus without biting incidents, Iran 1990–2010. *Journal of Clinical Virology* 54(3), 251–254.

Tariq, W.U., Shafi, M.S., Jamal, S. and Ahmad, M. (1991) Rabies in man handling infected calf. *The Lancet* 337(8751), 1224.

Tenzin (2016) *Imported Rabies Case in Pet Dog at Haa town: Investigation and Risk Assessment Report*. National Centre for Animal Health, Department of Livestock, Thimphu.

Tenzin, T., Dhand, N.K., Dorjee, J. and Ward, M.P. (2010a) Re-emergence of rabies in dogs and other domestic animals in eastern Bhutan, 2005–2007. *Epidemiology and Infection* 139(2), 220–225.

Tenzin, T., Sharma, B., Dhand, N.K., Timsina, N. and Ward, M.P. (2010b) Reemergence of rabies in Chhukha District, Bhutan, 2008. *Emerging Infectious Diseases* 16(12), 1925–1930.

Tenzin, T., Dhand, N.K. and Ward, M.P. (2012a) Anthropogenic and environmental risk factors for rabies occurrence in Bhutan. *Preventive Veterinary Medicine* 107(1–2), 21–26.

Tenzin, Wangdi, K. and Ward, M.P. (2012b) Human and animal rabies prevention and control cost in Bhutan, 2001–2008: the cost–benefit of dog rabies elimination. *Vaccine* 31(1), 260–270.

Tenzin, T., McKenzie, J.S., Vanderstichel, R., Rai, B.D., Rinzin, K. *et al*. (2015) Comparison of mark-resight methods to estimate abundance and rabies vaccination coverage of free-roaming dogs in two urban areas of south Bhutan. *Preventive Veterinary Medicine* 118(4), 436–448.

Tenzin, T., Namgyal, J. and Letho, S. (2017) Community-based survey during rabies outbreaks in Rangjung town, Trashigang, eastern Bhutan, 2016. *BMC Infectious Diseases* 17(1), 281.

Tenzin, T., Rinzin, K., Penjor, K., Dukpa, K., Jamtsho, R.K. *et al*. (2019) Rabies prevention and control

program in Bhutan: self-assessment using SARE tool. *Bhutan Journal of Animal Science* 3(1), 66–76.

Tenzin, T., Lhamo, K., Rai, P. B., Tshering, D., Jamtsho, P. *et al*. (2020) Evaluation of a rapid immunochromatographic test kit to the gold standard fluorescent antibody test for diagnosis of rabies in animals in Bhutan. *BMC Veterinary Research*, 16, 1–8.

Tshedup, Y. (2020) Engaging residents to curb dog population, Kuensel. Gelephu, Bhutan, 14 January 2020. Available at: https://kuenselonline.com/engaging-residents-to-curb-dog-population/ (accessed 14 January 2020).

Waltner-Toews, D., Maryono, A., Akoso, B.T., Wisynu, S. and Unruh, D.H.A. (1990) An epidemic of canine rabies in Central Java, Indonesia. *Preventive Veterinary Medicine* 8(4), 295–303.

Wangchuk, K., Wurzinger, M., Darabant, A., Gratzer, G. and Zollitsch, W. (2014) The changing face of cattle raising and forest grazing in the Bhutan Himalaya. *Mountain Research and Development* 34(2), 131–138.

Wertheim, H.F., Nguyen, T.Q., Nguyen, K.A., de Jong, M.D., Taylor, W.R. *et al*. (2009) Furious rabies after an atypical exposure. *PLoS Medicine* 6(3): e44.

Wilson, P.J. (2010) Evaluation of a postexposure rabies prophylaxis protocol for domestic animals in Texas: 2000–2009. *Journal of the American Veterinary Medical Association* 237(12), 1395–1401.

WHO (2018) *WHO Expert Consultation on Rabies: Third Report*. World Health Organization, Geneva, Switzerland.

WHO, OIE, FAO and GARC (2018) Zero by 30: the Global Strategic Plan to End Human Deaths from Dog-mediated Rabies by 2030. World Health Organization, Geneva, Switzerland. Available at: https://www.who.int/publications/i/item/9789241513838 (accessed 20 December 2019).

Zinsstag, J., Durr, S., Penny, M.A., Mindekem, R., Roth, F. *et al*. (2009) Transmission dynamics and economics of rabies control in dogs and humans in an African city. *Proceedings of the National Academy of Sciences of the United States of America* 106(35), 14996–15001.

Zinsstag, J., Mackenzie, J.S., Jeggo, M., Heymann, D.L., Patz, J.A. and Daszak, P. (2012) Mainstreaming One Health. *EcoHealth* 9(2), 107–110.

Zinsstag, J., Choudhury, A., Roth, F. and Shaw, A. (2015a) One Health economics. In: Zinsstag, J., Schelling, E., Waltner-Toews, D., Whittaker, M. and Tanner, M. (eds) *One Health: the Theory and Practice of Integrated Health Approaches*. CAB International, Wallingford, UK, pp. 134–145.

Zinsstag, J., Mahamat, M.B. and Schelling, E. (2015b) Measuring added value from integrated methods. In: Zinsstag, J., Schelling, E., Waltner-Toews, D., Whittaker, M. and Tanner, M. (eds) *One Health: the Theory and Practice of Integrated Health Approaches*. CAB International, Wallingford, UK, pp. 53–59.

Zinsstag, J., Waltner-Toews, D. and Tanner, M. (2015c) Theoretical issues of One Health. In: Zinsstag, J., Schelling, E., Waltner-Toews, D., Whittaker, M. and Tanner, M. (eds) *One Health: the Theory and Practice of Integrated Health Approaches*. CAB International, Wallingford, UK, pp. 16–25.

Zinsstag, J., Lechenne, M., Laager, M., Mindekem, R., Oussiguéré, A. *et al*. (2017) Vaccination of dogs in an African city interrupts rabies transmission and reduces human exposure. *Science Translational Medicine* 9(421): eaaf6984.