Cost-estimate and proposal for a development impact bond for canine rabies elimination by mass vaccination in Chad

Franziska Anyiam [a,b], Monique Lechenne [a,b], Rolande Mindekem [d], Assandi Oussigéré [c], Service Naissengar [c], Idriss Oumar Alfaroukh [c], Celine Mbilo [a,b], Daugla Doumagoum Moto [d], Paul G. Coleman [e], Nicole Probst-Hensch [a,b], Jakob Zinsstag [a,b,*]

[a] Swiss Tropical and Public Health Institute, PO Box, CH 4002 Basel, Switzerland
[b] University of Basel, Petersplatz 1, 4003 Basel, Switzerland
[c] Institut de Recherches en Elevage pour le Developpement, Boîte Postale 473, N'Djaména, Chad
[d] Centre de Support en Santé International, Boîte Postale 972, N'Djaména, Chad
[e] H2O Venture Partners, 33-35 George Street, Oxford OX1 2AY, UK

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ABSTRACT

Close to 69,000 humans die of rabies each year, most of them in Africa and Asia. Clinical rabies can be prevented by post-exposure prophylaxis (PEP). However, PEP is commonly not available or not affordable in developing countries. Another strategy besides treating exposed humans is the vaccination of vector species. In developing countries, the main vector is the domestic dog, that, once infected, is a serious threat to humans. After a successful mass vaccination of 70% of the dogs in N'Djaména, we report here a cost-estimate for a national rabies elimination campaign for Chad. In a cross-sectional survey in four rural zones, we established the canine : human ratio at the household level. Based on human census data and the prevailing socio-cultural composition of rural zones of Chad, the total canine population was estimated at 1,205,361 dogs (95% Confidence interval 1,128,008–1,736,774 dogs). Cost data were collected from government sources and the recent canine mass vaccination campaign in N'Djaména. A Monte Carlo simulation was used for the simulation of the average cost and its variability, using probability distributions for dog numbers and cost items. Assuming the vaccination of 100 dogs on average per vaccination post and a duration of one year, the total cost for the vaccination of the national Chadian canine population is estimated at 2,716,359 Euros (95% CI 2,417,353–3,035,081) for one vaccination round. A development impact bond (DIB) organizational structure and cash flow scenario were then developed for the elimination of canine rabies in Chad. Cumulative discounted cost of 28.3 million Euros over ten years would be shared between the government of Chad, private investors and institutional donors as outcome funders. In this way, the risk of the investment could be shared and the necessary investment could be made available upfront – a key element for the elimination of canine rabies in Chad.

1. Introduction

The most recent analysis estimates that annually worldwide, canine rabies causes 59,000 human deaths, over 3.7 million disability-adjusted life years (DALYs) and 8.6 billion USD economic loss (Hampson et al., 2015). Clinical rabies can be prevented by post-exposure prophylaxis (PEP). However, often PEP is either not available or not affordable in developing countries. Even if PEP were subsidized, out-of-pocket expenses remain a huge cost burden to affected families, exceeding 2–3 months wages (Zinsstag et al., 2009; Frey et al., 2013). Clearly any human exposed to a suspected rabid animal bite must receive PEP. However, the use of PEP alone will never interrupt rabies transmission. In developing countries, the most important vector is the domestic dog, which once infected, is a serious threat to humans (Wandeler et al., 1993). Only mass vaccination of dogs can eventually interrupt transmission and lead to the elimination of the disease.

* Corresponding author at: Swiss Tropical and Public Health Institute, PO Box, CH-24002 Basel, Switzerland.

E-mail address: jakob.zinsstag@unibas.ch (J. Zinsstag).

Boegel et al. (Bogel and Meslin, 1990) showed that after 15 years a canine rabies control programme consisting of a combination of PEP and canine vaccination becomes more cost-effective than PEP alone (Bogel and Meslin, 1990). This is because the use of PEP alone never interrupts human exposure. A recent simulation of canine rabies mass vaccination in an African city showed that the break-even of the cost of canine rabies vaccination and PEP can occur already after six years (Zinsstag et al., 2009). Because of the low reproductive number of canine rabies transmission, the World Health Organization (WHO) estimates that the immunization of 70% of the canine population could interrupt transmission and prevent the virus from spreading and, thus, rabies could be eliminated (WHO, 1987). The cost of canine mass vaccination should eventually break even with the cumulated cost of human PEP.

However, dog owners in West and Central Africa are often not able to pay for the vaccination of their dogs. In Chad fewer than 19% of the dogs are vaccinated by their owners. In a willingness to pay study that followed a mass vaccination campaign paid by the owner we could show that the reported willingness to pay corresponded well with the actually achieved vaccination coverage (Dürr et al., 2008; Durr et al., 2009). In order to reach a sufficiently high coverage in West and Central Africa, canine mass vaccination campaigns should therefore be free to the owner and freedom from canine rabies should be recognized as a public good.

The Global Alliance for Rabies Control works towards worldwide canine rabies elimination by 2030. After the eradication of Poliomyelitis, and compared to onther ongoing elimination efforts like Guinea worm, malaria and tuberculosis, canine transmitted human rabies is one of the most promising next candidate for global elimination because of its low reproductive number of less than 2. To achieve the elimination of canine transmitted rabies, interventions must be directed towards the domestic dog. This requires a close cooperation between public health and animal health, called "One Health" (Zinsstag et al., 2015). Latin American countries have made enormous progress in this regard and strong efforts are underway in South-East Asia (Hampson et al., 2007). In July 2015, the Pan African Rabies Control Network (PARACON) was founded with the clear aim of worldwide canine rabies elimination.

The elimination of an infectious disease such as rabies requires a highly-coordinated and concerted effort to reach all affected areas of a country in a short time frame. Considerable upfront funding is required to start the mass vaccination and reach a high enough coverage to interrupt transmission. A city-wide canine rabies elimination campaign in N'Djaména at a scale of 35,000 dogs and a human population of 1.1 million was able to do this with the engagement of the Chadian state and private donors (Lechenne et al., 2016). For the mobilization of the necessary funding for a country-wide mass vaccination campaign, alternative financing models are necessary, as neither national states, nor institutional donors are able to provide large amounts upfront. There is a growing interest among development donors and impact investors in the use of so-called "Development Impact Bonds" (DIB): Private investment provides upfront capital for development programmes, only calling on donor funding to repay capital and a potential return based on achieved results (Hughes, 2014), (Welburn and Coleman, Chapter 18 in (Zinsstag et al., 2015)).

The present study intends to contribute to the efforts of PARACON by estimating the cost of canine rabies elimination on a national scale for an African country by providing a comprehensive cost estimate and a proposal for a DIB for the elimination of canine rabies in Chad. A cost estimate for Chad will allow the extrapolation of the costs of campaigns in other countries of the Sahel (Dürr et al., 2008; Durr et al., 2009; Zinsstag et al., 2009).

2. Materials and methods

2.1. Canine population and cost estimate

2.1.1. Study area

Chad is a landlocked country located in Central Africa and is spreading over 1.284 million km². Geographically, Chad is divided into three distinct regions: the Sahara Desert in the north bordering Libya, the Sahelian belt and the Sudanese savannah in the south bordering the Central African Republic. Administratively, Chad is divided into 23 regions and each region is headed by a governor. Regions are divided into 61 departments each lead by a prefect. The departments are again divided into sub-prefectures (200 in total) comprising each a number of different cantons (over 400 in total) led by a chief of canton. Within the cantons, the smallest administrative entity in a rural setting is the village with its village chief.

58% of Chadians are Muslim (the vast majority Sunni) predominantly inhabiting northern Chad. Christians (19% Catholics, 16% Protestants), Animists (4%) and others (3%) primarily live in the southern regions (INSEED, 2009).

2.1.2. Sampling procedure and data collection

For a household study of the canine: human population ratio, the Sahara area of Borkou-Ennedi-Tibesti (BET) was omitted, having a negligible canine population. The remainder of Chad was divided into north (predominantly Sahelian) and south (predominantly Savannah) regions and was subjected to stratified multilevel sampling (Mbilo et al., 2017). Two northern regions and two southern regions (4 regions in total) were randomly selected, with selection probability proportional to the size of the population. In each region, one department was selected proportional to size (4 departments in total) and in each department 10 villages were randomly selected (40 villages in total). As data on the population at village level was not available, simple random sampling was used. The departments sampled were Kouh Ouest in the region of Logone Oriental, Grand Sido in Moyen Chari, Dar Tam in the region Wadi Fira and Guera in the region Guera. Details of the characteristics of the studied regions are provided in the companion paper on rabies awareness and canine ownership (Mbilo et al., 2017). The household study was approved by the ethical review board of the cantons of Basel, Switzerland (Ethik Kommission beider Basel, EKBB ref. 168/13, 29 July 2013) and authorized by the Chadian public health authorities.

2.1.3. Canine: human ratio

The estimation of the canine: human ratio is based on results of the data collection as well as recommendations by Chadian experts at the *Institut de Recherches en Elevage pour le Development (IRED).* It was assessed for every administrative region of Chad. The canine: human ratio is largely determined by the socio-cultural and religious composition of a region. Essentially, there are more dogs per humans in Christian/Animist communities than in Muslim communities (Mbilo et al., 2017). Hence empirically observed canine: human ratios were assigned to the relative numbers of Christians/Animists and to Muslims (Table 1). For every region the overall canine population was summed up. The overall total canine population of Chad was then obtained from the sum of canines in all regions. For the variability of the canine population we took the overall variation of the canine: human ratio of 1:6.3 to 1:9.7 from Mbilo's study (Mbilo et al., 2017).

2.1.4. Organization of the vaccination campaign

Decentralized operations are important for the administration of a nationwide vaccination campaign. The 61 departments of Chad