Vaccine xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Cost-effectiveness of mass dog rabies vaccination strategies to reduce human health burden in Flores Island, Indonesia

Ewaldus Wera [a,b,*], Monique C.M. Mourits [b], Henk Hogeveen [b]

[a] Animal Health Study Program, Kupang State Agricultural Polytechnic (Politeknik Pertanian Negeri Kupang), Jl. Prof. Dr. Herman Yohanes, Penfui Kupang, 85011 West Timor, Indonesia

[b] Business Economics Group, Wageningen University, Hollandseweg 1, 6706 KN Wageningen, The Netherlands

ARTICLE INFO

Article history:
Received 18 November 2016
Received in revised form 9 September 2017
Accepted 3 October 2017
Available online xxxx

Keywords:
Cost-effectiveness
Dog
Rabies
Vaccination strategies
Post-exposure treatment
Years of life lost

ABSTRACT

The cost-effectiveness of different mass dog rabies vaccination strategies, defined as the costs per year of life lost (YLL) averted was evaluated for a period of 10 years by means of a dynamic simulation study for a typical village on Flores Island.

In the base strategy (no dog vaccination and no post-exposure treatment (PET) of human bite cases), the model showed that the introduction of the virus by one infectious dog into an isolated village with 1500 inhabitants and 400 dogs resulted in 881 YLLs during a 10-year simulation period, which is equivalent to 30 human rabies cases. An annual dog vaccination campaign with a coverage of 70% using a short-acting vaccine saved 832 YLLs, while the cumulative costs for the public sector were US$3646 or US$4.38 per YLL averted. Switching to a long-acting vaccine, the annual vaccination strategies with a coverage of 50% (AV_156_50) or 70% (AV_156_70) reduced the baseline YLLs from 881 to respectively 78 and 26 YLLs with cumulative costs of US$3716 and US$2264 or US$4.63 and US$2.65 per YLL averted, respectively. In general, dog vaccination was more cost-effective than PET alone (US$2.65–4.63 per YLL averted versus US$23.29 per YLL averted). Although a combination of PET with AV_156_70 was less cost-effective compared to AV_156_70 alone, this strategy was able to prevent all human deaths due to rabies. A combination of PET with annual vaccination using a short-acting vaccine at a coverage of 50% was far from being cost-effective, suggesting that the currently applied rabies control in Flores Island is not an efficient investment in reducing human rabies burden. An increased investment in either an increase in the current coverage or in a switch from the short-acting vaccine to the long-acting vaccine type would certainly pay off.

1. Introduction

Since its introduction in 1998, rabies has posed a serious public health threat to the 1.8 million inhabitants of Flores Island. The health impact during the period 1998–2012 coincided with 96 officially registered human cases [1]. However, this number underestimates the real rabies burden in Flores, since this number is only based on the number of rabies patients who visited hospitals or public health centres during the rabies clinical manifestation. Currently the number of human cases is estimated at 8 cases a year (Sikko, personal communication, Animal Health and Husbandry Department of Sikka Regency).

Annually, more than 2500 persons visit a hospital to seek for post-exposure treatment (PET = actual bite treatment including wound cleaning, a series of vaccine injections and/or immunoglobulin injection) after being exposed by a suspected rabid dogs [2]. Around 86% of these registered bite cases actually receive PET, which is provided free of charge to dog-bite victims by the local government. The annual costs for PET in Flores Island have been estimated to be US$0.6 million [2]. PET is, however, not a strategic solution to rabies as it does not prevent rabies transmission from dogs to humans and hence the occurrence of rabies cases in humans [3]. Elimination of rabies in the dog population (the reservoir population) through mass dog vaccination programs is, therefore, seen as a better approach to prevent rabies in humans [4,5].

Wera et al. [6] evaluated the costs of various mass dog vaccination campaigns in Flores Island in relation to the number of rabid dog cases averted by means of a simulation study on the expected virus transmission among dogs within a village. Results showed

* Corresponding author at: Animal Health Study Program, Kupang State Agricultural Polytechnic (Politeknik Pertanian Negeri Kupang), Jl. Prof. Dr. Herman Yohanes, Penfui Kupang, 85011 West Timor, Indonesia.

E-mail addresses: ewaldus.wera@yahoo.com, nanawaldi@yahoo.com (E. Wera).

https://doi.org/10.1016/j.vaccine.2017.10.009
0264-410X/

that repeated annual mass vaccination using a long-acting vaccine at a coverage of 70% was the most cost-effective strategy in reducing dog rabies cases. Rabies was not eliminated from the dog population with annual vaccinations using short-acting vaccines at a coverage of 50%, as is the current practice in Flores.

The study of Wera et al. [6] did not evaluate the benefits of dog vaccination campaigns on saved human life and prevented PET. In order to fully appreciate the impact of dog rabies control measures these benefits need to be evaluated as well. This study aimed to evaluate the cost-effectiveness, defined as the costs per year of life lost (YLL) averted, of mass dog vaccination strategies using a dynamic simulation model representative for the situation in Flores Island.

2. Materials and methods

To evaluate the impact of different dog rabies vaccination campaigns on reducing human rabies cases, we extended our previously developed SEIVR (susceptible, exposed, infectious, vaccinated, and immune) deterministic model [6] reflecting the rabies transmission dynamics among dogs with the transmission dynamics of rabies from dogs to humans.

2.1. General outline of the dog SEIVR model

The SEIVR model of Wera et al. [6] simulates the transmission of rabies which is only introduced once at the beginning of the simulation in a closed dog population of a theoretical average village in Flores, characterised by a population of 1500 people owning a total of 400 dogs. An average village in Flores Island has a length of 3.4 km and a width of 0.5 km [6] and reflects an area in which a group of households or local communities lives together based on the same cultural and ancestral background. The village was chosen as the epidemiological unit as dogs on Flores Island are living closely with their owners within the village area and are rather isolated from dogs of other villages. In the context of an isolated village, the migration of dogs only occurs by humans and not unintentionally as the distances between the villages are too large for dogs to come in contact with each other just by wandering off. Simulation starts with the introduction of one infectious dog into the village [6]. Transmission is subsequently simulated for a period of 10 years by time steps of a week. Current vaccination campaigns in Flores Island are based on structural planning and a such not driven by a specific disease condition. Within the model, detection triggers a reactive vaccination campaign followed by structural vaccination campaigns until the rabies epidemic is under control (defined as a situation where the number of infected dogs is less than 0.50 for 26 consecutive weeks). Detection occurs at the moment when at least two infectious dogs are present within one time step. This assumption is based on the expectation that this number of infectious dogs will cause an unusual number of bite cases per week, hence triggering the local community to report the presence of the disease to the Animal Health Authority. Upon this reporting the vaccination campaign is expected to be initiated with one week. In this context, the reactive vaccination in this study started 3 months after the virus introduction into a village. See for a detailed description on the model and the used dog rabies transition rates Wera et al. [6].

2.2. Transmission of rabies from dogs to human

Infected dogs show clinical signs in either furious or paralytic forms [7]. The furious form is characterised by aggression and frequently wandering throughout the village [8]. The paralytic form is characterised by paralysis of the throat and masseter muscles [8] due to peripheral nerve dysfunction [8,9], resulting in death without biting any other dogs or humans. Therefore, only dogs in the furious form were considered to be able to spread the virus [8,9]. Thus, the number of human rabies cases at time t (N_t) is based on the number of infectious dogs in time t-1 (I_{t-1}), the proportion of furious infectious dog (F), the proportion of furious infectious dogs that bites a human (FBH), the proportion of bite-victims receiving PET (PPET), and the probability of a bite-victim developing rabies if there is no PET (PRH) (Table 1):

$$N_t = I_{t-1} \times F \times FBH \times (1 - PPET) \times PRH \quad (1)$$

Table 1
Model parameters used in the prediction of human life years lost (YLL) due to rabies infection.

Para-meters	Value	Reference	Description
F	0.7	Assumption[a]	Proportion of furious rabid dogs among infectious dogs per week
FBH	0.20	Experts[b]	Proportion of furious rabid dogs bite human per week
PPET	0.56	Wera et al. [24]	Proportion of bite-victims receiving PET[g]
P1	0.07	PHD[c]	Probability of a bite to the head or neck
P2	0.21	PHD[c]	Probability of a bite to the upper extremity (arm or hand)
P3	0.06	PHD[c]	Probability of a bite to the trunk of the body
P4	0.66	PHD[c]	Probability of a bite to the lower extremity (leg of foot)
P5	0.55	Shim et al. [11]	Probability of developing rabies following a bite to the head by a rabid dog
P6	0.22	Shim et al. [11]	Probability of developing rabies following a bite to the upper extremity by a rabid dog
P7	0.09	Shim et al. [11]	Probability of developing rabies following a bite to the trunk by a rabid dog
P8	0.12	Shim et al. [11]	Probability of developing rabies following a bite to the lower extremity by a rabid dog
PRH	0.17	Calculated[d]	Probability of developing rabies following a bite by a rabid dog
C	0.1658	WHO[e] [15]	Age-weighting correction constant
B	0.04	WHO[e] [15]	Age-weighting function constant
A	Varies		Age of death
L	Varies		Duration of time lost due to premature death
R	0.03	WHO[e] [15]	Discount rate per year
rw	0.000569	Calculated[f]	Discount rate per week

[a] Assumption based on WHO [7].
[b] Derived from the expert knowledge of five public servants/veterinarians who were involved in the back tracing of bite cases in rabies infected villages on Flores Island. The experts were individually interviewed in 2013 during field work related to the study of Wera et al. [24].
[c] PHD = Public Health Department of Sikka Regency (unpublished data).
[d] Calculated based on the equation: PRH = (P1 * P5) + (P2 * P6) + (P3 * P7) + (P4 * P8).
[e] WHO = World Health Organisation.
[f] rw = (1 + r)^(1/52)–1.
[g] PET = Post-Exposure Treatment.