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Surveillance guidelines for disease elimination: A case study of canine rabies

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ABSTRACT

Surveillance is a critical component of disease control programmes but is often poorly resourced, particularly in developing countries lacking good infrastructure and especially for zoonoses which require combined veterinary and medical capacity and collaboration. Here we examine how successful control, and ultimately disease elimination, depends on effective surveillance. We estimated that detection probabilities of <0.1 are broadly typical of rabies surveillance in endemic countries and areas without a history of rabies. Using outbreak simulation techniques we investigated how the probability of detection affects outbreak spread, and outcomes of response strategies such as time to control an outbreak, probability of elimination, and the certainty of declaring freedom from disease. Assuming realistically poor surveillance (probability of detection <0.1), we show that proactive mass dog vaccination is much more effective at controlling rabies and no more costly than campaigns that vaccinate in response to case detection. Control through proactive vaccination followed by 2 years of continuous monitoring and vaccination should be sufficient to guarantee elimination from an isolated area not subject to repeat introductions. We recommend that rabies control programmes ought to be able to maintain surveillance levels that detect at least 5% (and ideally 10%) of all cases to improve their prospects of eliminating rabies, and this can be achieved through greater intersectoral collaboration. Our approach illustrates how surveillance is critical for the control and elimination of diseases such as canine rabies and can provide minimum surveillance requirements and technical guidance for elimination programmes under a broad-range of circumstances.

1. Introduction

Surveillance is a critical element in the control and elimination of infectious diseases [1]. Effective surveillance systems allow early detection and reporting of cases, vital for initiating timely responses and enabling informed decisions about when and where to intensify control efforts. Once interventions are implemented, surveillance is also essential to generate data on the progress and cost-effectiveness of such programmes, which are essential for their sustainable implementation. In practice the quality of surveillance and therefore the probability of disease detection can vary considerably, with consequences for

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disease control such as outbreak containment or discontinuation of control measures once freedom from disease has been achieved. Weak surveillance may therefore result in delayed control interventions and complacency [2] and can jeopardize chances of disease elimination [3]. As control efforts progress towards elimination, surveillance becomes even more critical in order to detect new incursions. "Unless an effective reporting and surveillance programme is developed, there is no prospect whatsoever for a successful eradication programme" D.A. Henderson [4].

Rabies is one of the most feared zoonoses, nearly always resulting in fatal acute encephalitis [5]. Although rabies is maintained and transmitted by a wide range of species and may never be eradicated from all species, it is feasible to eliminate canine rabies [6], which is responsible for the vast majority of human cases worldwide and is of the greatest public health concern [7,8]. Canine rabies is not only a major burden in endemic countries where thousands of human deaths are estimated to occur annually [7], but also in previously rabies-free areas where risks of re-emergence have been increasing over the last decade [e.g. 9, 10, 11]. A 'One Health' approach is the most effective way of protecting humans from canine rabies, as infection is maintained in domestic dog populations. A number of countries have achieved considerable successes in canine rabies elimination through mass dog vaccination [12–14]. The feasibility and cost-effectiveness of this approach has been strongly advocated in recent years [15], with major international public and animal health organisations declaring global canine rabies elimination as a realistic goal (e.g. WHO http://www.who.int/rabies/bmgf_who_project/en/index.html; OIE http://www.oie.int/en/for-the-media/editorials/detail/article/oies-commitment-to-fight-rabies-worldwide). The degree of success of national and global canine rabies elimination efforts is however heavily reliant on effective epidemiological surveillance, which should ensure that intervention impacts can be monitored through time and outbreak responses initiated where necessary. Indeed, response times to incursions are dependent on the speed of first detection (Table 1), hence surveillance plays a major role in triggering an early response.

For vaccine preventable diseases, surveillance typically improves once a control programme gets underway, as observed during eradication efforts for polio, and more generally during the expanded programme on immunization (EPI) for the control of measles and other childhood infections [1,16]. However, in developing countries routine surveillance may initially be vestigial to non-existent with limited reporting accounting for substantial underestimation of cases [3]. For example, prior to the establishment of intensive surveillance activities for smallpox, estimates of reporting rates in Indonesia and West Africa varied from <1% of cases to 8% in urban areas [Keja (1968) reported in 3, 17]. Underreporting is particularly severe for diseases of zoonotic origin where very few examples of well-integrated surveillance mechanisms exist [18]. For rabies, largely complete and well-functioning surveillance and data management systems are maintained in countries where canine rabies has either been eliminated (U.S.A. http://www.cdc.gov/rabies/location/usa/surveillance/index.html; Europe http://rbe.fli.bund.de (Rabies-Bulletin-Europe)) or is under control and prospects for elimination are good (South America http://siepi.panaftosa.org.br/anuais.aspx), in contrast to deficient surveillance operating in most endemic countries. Surveillance capacity is also often particularly weak in areas without a history of rabies. Health workers play an integral role in the surveillance of strictly human diseases, and in previously rabies free-areas the speed of response to outbreaks has sometimes depended on health workers identifying the disease in humans (e.g. Bali and Nias in Indonesia, Table 1). Ultimately a One Health approach involving the close cooperation of medical and veterinary workers is required for effective surveillance of rabies and other zoonoses [19].

Limited resources mean that trade-offs inevitably exist between maintaining sensitive surveillance systems and mobilizing responses to an incursion once detected by a less sensitive, passive surveillance system. Recent emergences of rabies highlight the risks posed, including massive economic repercussions and need for continuous public health and veterinary staff mobilization, from inadvertent introductions if effective surveillance and response measures are not in place [9,11,20]. In endemic areas surveillance for canine rabies typically involves passive reporting of clinically suspected human and/or animal cases, and ideally laboratory diagnosis of suspect animal cases particularly if they have caused possible human exposures (although in many areas this is not carried out). While a lack of proper diagnostic facilities often limits rabies surveillance, weak field capacity for investigating cases and poorly functioning reporting networks are perhaps a more enduring problem [18].

OIE guidelines for a 'rabies free country' in Article 8.10.2 of the Terrestrial Animal Health Code require "an effective system of disease surveillance is in operation" and "no case of indigenously acquired rabies infection has been confirmed in man or any animal species during the past 2 years." [21]. WHO guidelines on the levels of surveillance needed to certify rabies-free status indicate that "a minimum number of samples from suspect cases" should be tested, and that "for domestic animals, in particular dogs and cats, the number of samples to be tested should be between 0.01–0.02% of the estimated population" [8]. However, clarity is still needed on for example, definitions for targeted surveillance, control strategies to rabies incursions and maintaining rabies-freedom, and quantitative surveillance assessments for decision-making within rabies elimination programmes.

Although surveillance is an essential component of control programmes, this is often not well recognized in developing countries and is exacerbated by poor infrastructure and health and veterinary capacity. However, it is precisely these countries where endemic canine rabies remains, and surveillance is therefore necessary to monitor the impact of any control efforts. In light of these surveillance issues, and growing advocacy for elimination of canine rabies, here we aim to understand how successful rabies control and elimination depends on the effectiveness of surveillance by investigating different containment strategies guided by surveillance indicators. Specifically we