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Canine rabies and human health

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Rabies is a frightening disease, with horrifying symptoms including intense pain and suffering, biting behaviour which can pose a lethal threat to loved ones, and near certain mortality following disease onset. Rabies also poses severe financial burdens on rural villages (1). The mainstream scientific and public health communities have seen large changes in how rabies is viewed over the last 10 years. Virtually all human cases of rabies are due to canine strains (2), which are maintained primarily by domestic-dog populations. Spread among domestic dogs can be effectively prevented by vaccination, and canine rabies is no longer a public-health threat in wealthier parts of the world. By the turn of the century, public-health attention to rabies had languished, and scientific attention focused on threats posed to people by wildlife rabies in developed countries (e.g. fox and raccoon rabies in North America, (3)) and on threats *to* endangered wildlife (e.g. Ethiopian wolves (4)). Recent years have seen renewed recognition of the importance of canine rabies to human health: the scientific community has increasingly embraced dog rabies as an interesting and important field of study, and the public-health community has ramped up control efforts, leading to striking control successes, particularly in the Americas. In response to such successes, WHO has endorsed the goal of eliminating deaths from "dog-mediated" rabies by 2030 (2).

This article discusses a series of papers published from 2007, by a group centred around Katie Hampson, Magai Kaare, and Tiziana Lembo. The papers are based on ground-breaking work that they did tracing canine rabies in Tanzania, as well as analyses of data from other parts of the world. The group has continued to be involved in fighting canine rabies throughout the world (with the exception of Kaare, who died in 2008 in a car accident in Tanzania). I played a minor role in most of these studies and was listed as an author on some them.

How do rabies epidemics cycle?

Rabies epidemics have a natural tendency to cycle: after an outbreak spreads through a population, reducing population density, the disease would be expected to decline. Once the disease declines, the density of dogs will build up. Once density is high enough, another outbreak can occur. And so on. A 2007 review of published and government data (5) showed that rabies cycled with a period of 3-6 years across southern and eastern Africa, and that these cycles were geographically synchronized across the region, suggesting that canine rabies is a regional problem, and that each country's control efforts are likely affecting neighbouring countries.

The researchers also used a mathematical model to study how rabies epidemics cycle. They showed that observed cycles were too fast to be easily explained simply by the mechanism described above, but that they *could* be easily explained by adding the effect of "reactive vaccination" – in other words, if people are responding to rabies epidemics by carrying out vaccination campaigns, and if they respond to declines in rabies by being less active in vaccination, this could speed up cycles and match the observed data. The authors concluded, that consistent and co-ordinated vaccination campaigns could potentially eliminate canine rabies across southern and eastern Africa, where much of the rabies burden is concentrated.

This optimistic prediction received substantial support from a 2008 study of rabies in and around Serengeti National Park in Tanzania (6). This study focused on rabies spread between different species of carnivores in an area with a large number of wild carnivores. The authors used genetic and spatiotemporal data to infer how rabies spread between species, and found that maintenance of rabies in this system was dependent on spread within the domestic-dog community. In other words, they found that the amount of spread within domestic dogs was sufficient to sustain rabies transmission, but the amount of spread within the wild carnivore population was not. In other words, if (and only if) domestic-dog transmission could be reduced sufficiently, rabies could be eliminated from the region. On the other hand, they found that spread among wild carnivores (and from wild carnivores to dogs) was sufficient to increase the amount of control required for elimination. Since the area studied has an unusually large amount of interaction between wild carnivores and domestic dogs, the authors concluded that domestic dogs were likely the key to control of canine rabies throughout Africa.

Vaccination programs for canine rabies control

The group was actively involved in both promoting and studying vaccination campaigns. A 2009 paper (7) laid out their findings from Serengeti district, a medium-density area with an economy based on agriculture and livestock, similar to large areas of rural Africa, and from neighbouring Ngorongoro district, with a more traditional economy based only on livestock. They found that organized "central-point" campaigns, where residents are encouraged to bring dogs to a vaccination centre at a pre-announced time were highly effective, and cost effective, in Serengeti district. In Ngorongoro district, achieving high coverage was both more difficult and more expensive, but still affordable (around $5 per dog). This study also found that the proportion of feral dogs (dogs not owned by humans) was low, even in these rural (sometimes very rural) areas, further encouraging optimism that vaccination programs can bring canine rabies under control.

The keystone paper of this series reported on an intensive program of tracing contacts of rabid dogs in Serengeti and Ngorongoro districts (8). Teams led by Hampson recorded over 3000 potential transmission events (they have since traced many more), and provided the best available data about natural history of rabies in domestic dogs, including information about the time from receiving a bite until symptoms develop (the incubation period), the time from symptoms until death (the symptomatic period), and biting patterns of infected dogs. The study also estimated the overall ability of rabies to spread in this population, measured as the average number of cases directly caused by a focal case (the reproductive number), and showed that this reproductive number decreased roughly as expected with vaccination, but was relatively insensitive to dog density. This result implies that culling of healthy dogs, and other attempts to reduce dog density, are likely to be a less effective than vaccination at controlling rabies.

The optimism of these papers has largely been validated, particularly in the Americas, where dog-transmitted rabies has declined sharply as a result of a 30-year commitment, and is now targeted for elimination (9). Rabies has been identified as a neglected tropical disease, bringing added attention to control measures, and programs continue to explore practical strategies for elimination across the world (10). Much still remains to be done, however. rabies continues to exact a large burden of mortality, associated with concomitant amounts of fear and expense, throughout much of Africa and Asia (11). This is a disease that can be eliminated as a public-health problem with consistent and concerted attention: hopefully, this attention will be forthcoming.

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