Communication Arising: Knowledge gaps about rabies transmission from vampire bats to humans

M.B. Fenton, D.G. Streicker, P.A. Racey, M.D. Tuttle, R.A. Medellin, M. J. Daley, S. Recuenco and K. E. Bakker

Bakker *et al.*[1] cited the incidence of human rabies transmitted by common vampire bats in high risk environments in South America to be up to 960 human deaths per 100,000 people, an estimate originally published by Schneider *et al.*[2]. This alarming number sparked a series of correspondence among bat researchers and advocates which highlighted major knowledge gaps in the burden of human rabies transmitted by vampire bats and the challenges that poorly communicating these uncertainties pose for bat conservation and human health. This letter elaborates upon these emergent issues with the aim of facilitating effective communication of risk and encouraging research initiatives to generate more generalizable estimates of human rabies incidence.

The risk estimate of Schneider *et al.*[2] originated from a single community in Brazil that was specifically selected because of the high incidence of bats feeding on humans (23% of inhabitants had been bitten within the prior year). Similar frequencies of bat bites on humans (e.g., 23, 27, 41, 70, 88% of inhabitants) are not unusual [3–6], but the nature of surveys – always non-random and often following human rabies outbreaks - means the true frequency of communities that experience frequent bat attacks is mostly unknown.

The second impediment to generalizable estimates of the burden of human rabies is a direct consequence of the epidemiology of vampire bat rabies. The virus occurs sporadically in local bat populations, likely maintained through extinction-recolonization dynamics or other complex spatiotemporal processes which remain largely unknown [7–10]. The frequency of outbreaks within bat populations and the proportion of bats that become infected are therefore key variables needed to estimate human risk. Although data are limited, the frequency of outbreaks appears low (S. Recuenco unpublished data). Instances of repeated human rabies outbreaks affecting the same community are infrequently documented, suggesting prolonged periods without local viral circulation. The proportion of bats infected during outbreaks is also poorly known, but estimates as high as 10% of a colony have been reported [11,12], creating the potential for substantial human mortality. Between 1 and 39 people in any village have been infected during an outbreak. Because outbreaks generally occur in remote communities comprised of only several hundred people, substantial proportions (1-7% of total inhabitants) may be directly impacted [5,13–15]. Clearly, when outbreaks occur, local risk and health impacts are substantial and require action.

Averaged averaged over space and time, the likelihood of human rabies is exceedingly low. This creates an obvious communication problem that can generate conflicts between public health and bat conservation. Spatiotemporal averages do not adequately capture local risk which compromises ongoing public health initiatives to prevent bat bites (e.g., distribution of bed nets) and rabies (i.e., mass pre-exposure vaccination campaigns) in high risk areas [16]. Focusing solely on risk estimates from outbreaks makes people fearful of bats, which has three negative impacts. First, it alarms people un-necessarily. Second it amplifies the negative public image of bats. Third, it casts a pall over efforts to conserve bats.

By discussing the limitations of all available estimates, we hope to encourage a more nuanced discussion of human rabies including public health practitioners and bat conservationists. Looking forward, an alternative approach to estimating the burden of vampire bat-transmitted human rabies would be to utilize case data reported to international health agencies (e.g., Pan American Health Organization or World Health Organization) [17]. Doing so reliably requires statistical models that use auxiliary data to accommodate under-reporting of disease incidence. While this has been achieved for dog-transmitted rabies and rabies transmitted from vampire bats to livestock [18–20], we are unaware of efforts to incorporate this approach to infer the burden of human rabies transmitted by vampire bats, where reporting can be hindered due to cultural, socioeconomic, educational, and geographic factors [14]. Understanding the proportion of human communities that live in high-risk conditions (e.g., through geographically randomized questionnaires) and the frequency and magnitude of rabies outbreaks in bat populations (e.g., through longitudinal monitoring of wild bats) are critical knowledge gaps that must be filled to make such estimates meaningful.

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