Public Health Action

International Union Against Tuberculosis and Lung Disease
Health solutions for the poor

VOL 3 NO 1 PUBLISHED 21 MARCH 2013

Haematophagous bat bites in Ecuadorian Amazon: characterisation and implications for sylvatic rabies prevention

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http://dx.doi.org/10.5588/pha.12.0070

Objective: To characterise the risk factors of haematophagous bat bites and to provide information to contribute to the prevention of rabies in Ecuador.

Design: Cross-sectional study based on interviews with 3518 individuals, from which two sets of variables were generated: characteristics of haematophagous bat attacks in the previous year among humans and risk factors for being bitten.

Methods: Data were analysed using multivariate logistic regression models, taking history of bat bites in the previous year as the response variable.

Results: In the previous year 723 (20.6%, 95%CI 19.3–21.9) of the participants declared having received haematophagous bat bites and 50.4% in the previous month, giving an incidence rate of 10.4% (95%CI 9.6–11.6) per month. Sleeping on the floor or in a hammock (adjusted odds ratio [aOR] 1.58, 95%CI 1.21–2.06), not using a protective bed net (aOR 1.25, 95%CI 1.03–1.50) and living in a dwelling with permanent openings in the structure (aOR 1.49, 95%CI 1.12–1.95) were associated with a higher probability of bat bites. Those most affected were the group aged ⩽12 years (age 13–19 years, aOR 0.39, 95%CI 0.32–0.48; age ⩾20 years, aOR 0.67, 95%CI 0.50–0.90).

Conclusion: Primary prevention based on pre-exposure vaccination would be justifiable given the high dispersion of the population and the high incidence of bat bites. As a secondary protective measure, communities should work towards increasing the use of protective measures and putting barriers in permanent openings in their dwellings.

In Latin America an increase has been reported in the frequency of human and animal deaths from sylvatic rabies due to vampire bat bites.[1] The genetic and molecular markers that characterise genetic lineages of the sylvatic rabies virus variant in humans belong to the same rabies cycle as that of the vampire bat *Desmodus rotundus*.[2]

In cases of bites, the strategy employed has always been post-exposure vaccination, as there has been no progress in treatment, although there has been a breakthrough in the description and the analysis of the *Lissavirus* family and in the pathogenesis of this fatal disease.[3]

In 2010, it was reported that 90% of inhabitants in the Peruvian jungle had been bitten by haematophagous bats at least once in their lives.[4] In Ecuador, sylvatic rabies occurs throughout most of the Amazon territory. Previous sylvatic rabies outbreaks have been reported as part of the regular work of health teams, but there is no published information in the indexed literature.[5]

In December 2011, an outbreak of sylvatic rabies was declared in three indigenous communities of the Taisha canton in the province of Morona Santiago, on the southern border of the Ecuadorian Amazon.[6–8] Eleven deaths occurred, nine of which were in children aged <15 years. Autopsy samples were collected in only two of these patients and tested positive for a vampire bat rabies virus variant.

The first health action taken involved post-exposure anti-rabies vaccination, with seven daily doses and three boosters given to all inhabitants of these communities[9] (vaccine coverage of 97% was achieved at the seventh dose, involving 617 inhabitants).

In the second phase, the action was expanded to include the communities considered at risk, based on the flight radius of the vampire bat. Post-exposure anti-rabies vaccination coverage was 84.5% at the seventh dose (2453 inhabitants).

In other communities located 10–20 km around Taisha (40 000 inhabitants), a scheme of pre-exposure immunisation was implemented using a cell-culture vaccine; a coverage of 65% was achieved at the third dose.

The health action actively involved various institutions, with the goal of ensuring access to the affected communities by the health teams. This may involve a 15–40 min flight, followed by a walk or a canoe trip, which could take 2–15 h to reach the community.

Although the intervention in the canton of Taisha revealed that vampire bat (haematophagous) bites among the Amazon basin residents is a daily occurrence, they have not yet been characterised in Ecuador, and scarcely in the other Amazon countries.[10–12]

For this reason, in parallel with the vaccination process, a team conducted a questionnaire-based survey to study and record the conditions that characterise haematophagous bat bites.

The principal objective of the paper is thus to report the findings of this survey, justified on the basis of three issues. First, haematophagous bat bites constitute the transmission route of sylvatic rabies.[13] Second, although rabies is preventable, the fatality rate due to rabies is almost 100%.[14] Third, in the implementation of protective measures to prevent vampire bat bites in marginalised populations, in addition to other aspects, their

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KEY WORDS
bat bites; neglected disease; poverty

Received 1 October 2012
Accepted 18 January 2013

PHA 2013; 3(1): 85–89

world view must be taken into account so that prevention and control programmes will function adequately.

STUDY POPULATION, DESIGN AND METHODS

The study was conducted between February and April 2012. The field research team consisted of 10 investigators, eight of whom are fellows at the Ministry of Public Health of Ecuador, with one officer and one anthropologist. A senior statistician was included for data analysis.

The population studied belongs to the Achuar and Shuar groups, of whom the latter are the majority. Population dispersion and frequent temporary migration between communities, or sometimes even between countries, make it practically impossible to determine, a priori, the population census used for sampling communities and individuals. We therefore decided to work with the complete communities visited by the vaccination campaign during the months mentioned, obtaining an opportunistic sample for the survey of all members of each community who attended for vaccination on the scheduled date.

Questionnaire design

The questionnaire was developed based on surveys already published in Peru,[15,16] and administered to all family members; for children aged ⩽12 years it was answered by the father or mother. The questionnaire consisted of the following elements:

1 Characteristics of vampire bat attacks in humans and treatment measures: number of bites in the last year. This variable was analysed as history of bat bites within one year prior to the survey, labelled as 'bite history', together with the most recent bite that occurred in the last 30 days, labelled as 'bitten in the last month', sites of bites, time since the last attack and treatment measures (where the victim went for treatment, what treatment was given).
2 Risk factors for bites: presence of openings in the structure of the dwelling (absence of walls, openings between the walls), outdoor lighting left on throughout the night, usual sleeping place (bed, hammock or on the floor), use of protective bed nets when sleeping, presence of animals (cattle, pigs, horses, poultry, cats, dogs).

Statistical analysis

Associations between categorical variables were tested using the likelihood ratio (LR) and calculation of odds ratios (OR). The study variables were bites and 'bitten in the last month'. The reference categories used in the logistic regression model, corresponding to conceptually protective situations, were: outdoor lighting used during the night, no permanent openings in the structure of the house, a bed as the usual sleeping place, the use of a protective bed net, and no presence of cattle. For sex and age, the reference categories used were male and ⩽12 years.

The SPSS statistical package (PASW Statistics 18.0; SPSS Inc., Chicago, IL, USA) was used in all analyses.

Ethical aspects

The study protocol, approved by the Ecuadorian Ministry of Public Health, was submitted for approval to the highest authorities of the Achuar and Shuar populations, who gave their written consent. All families present on the day of the survey were invited to participate, and accepted to participate once each community assembly had made the decision to participate. Members of each community were also invited beforehand by the assembly to attend the community hall where the study was presented; and before the completion of the questionnaires, the head of each family, or their representative, provided signed informed consent. All members of the participating families were present when the questionnaires were completed, which was done in Spanish.

RESULTS

The 3518 participants came from 92 communities; the average age was 19.5 years (standard deviation 16.2, median 14.6): 25% of the participants were aged >30 years, and 50.1% were women. It was reported by 31.7% of the participants that they had changed their community of residence at least once in the last year.

Incidence of bites

A total of 723 (20.6%, 95% confidence interval [CI] 19.3–21.9) participants declared having been bitten at least once in the last 12 months (average 2.7, median 2), while 25% reported having more than three bites; the maximum was 30 bites. There were no differences between men and women, or in the number of attacks. In 366 (50.4%) of the cases, the most recent attack had occurred in the last 30 days, indicating an approximate incidence of 10.4% (95%CI 9.6–11.6) per month.

Characteristics of vampire bat attacks among humans and treatment measures

In 99% of cases, the attack had occurred while the victim was sleeping. The parts of the body most affected by bites were the head or neck in 377 (52.6%) cases, with differences depending on age group (LR 143.4, 6 degrees of freedom [df]; $P \leqslant 0.001$). Among children aged ⩽4 years this percentage rose to 73% (103/141). Bites on feet were reported in 274 (38.2%) cases overall, in 42.4% (36/85) of participants aged between 13 and 19 years, and in 21.1% (30) of those aged ⩽4 years. Hands were affected in 111 (15.5%) cases, and there were no differences in terms of age group.

In 646 (89.4%) cases, washing was the first therapeutic measure, with either hot or cold water, with or without soap. Of those bitten, 57 (7.9%) sought medical care later on, mostly from a health agent (health promoter, nurse, doctor), while 8 (1.1%) went only to a *shaman* or witch doctor.

Risk factors for a history of bat bites within the previous year (bite history)

Table 1 shows the descriptive results indicating the frequency of being bitten by a vampire bat within the previous year for each category of the studied factors.

ACKNOWLEDGEMENTS

The authors thank the Pan-American Health Organization (PAHO) for sponsoring the consultancy of Dr S Recuenco; Centers for Disease Control and Prevention, Atlanta, and R Douce and M Nelson for their support in the outbreak intervention.

This work was supported by the Ministry of Public Health of Ecuador with funds from the Vigilancia Zoonosis–Rabia, Dirección Nacional de Epidemiología, 2012, and grants for post-graduate studies in Family and Community Medicine at the Universidad Central del Ecuador, for the period 2011–2013. The participation of MFC was funded by PAHO, and MM was funded by AGAUR (Agencia de Gestió d´Ajuts Universitaris i de Recerca, SGR 2009 no. 1996) Generalitat de Catalunya.

The opinions and assertions contained herein are those of the authors and should not be interpreted as reflecting the official position or opinion of the Ministry of Health of Ecuador.

Conflict of interest: none declared.

TABLE 1 Descriptive characteristics of risk factors for history of bat bites within the previous year

Variable	Bite history: Yes *n* (%)	Bite history: No *n* (%)	Total *n* (%)
Sex			
Female	347 (19.7)	1415 (80.3)	1762 (50.1)
Male	376 (21.4)	1380 (78.6)	1756 (49.9)
Age, years			
0–4	142 (20.7)	544 (79.3)	686 (19.5)
5–12	315 (33.6)	622 (66.4)	937 (26.6)
13–19	88 (17.4)	419 (82.6)	507 (14.4)
⩾20	178 (12.8)	1210 (87.2)	1388 (39.5)
House with outdoor lighting			
Yes	72 (18.5)	317 (81.5)	389 (13.3)
No	633 (20.7)	2421 (79.3)	3054 (86.7)
Permanent openings in house structure			
Yes	630 (21.5)	2296 (78.5)	2926 (85.0)
No	75 (14.5)	442 (85.5)	517 (15.0)
Usual sleeping place			
Bed	480 (17.3)	2293 (82.7)	2773 (78.8)
Hammock or floor	243 (32.7)	501 (67.3)	744 (21.2)
Use of protective bed net			
Yes	274 (17.3)	1310 (82.7)	1584 (62.7)
No	187 (19.9)	755 (80.1)	942 (37.3)
Presence of cattle			
Yes	100 (17.6)	468 (82.4)	568 (16.5)
No	605 (21.0)	2270 (79.0)	2875 (83.5)

The most frequent categories in those who reported a history of bat bites within the previous year were: male, age ⩽12 years, house without outdoor lighting, house with permanent openings in the structure (walls, roof), hammock or floor as the usual sleeping place, absence of a protective bed net and not having cattle around the house.

Table 2 presents the crude OR values for the association between having a bite history and the above variables. Independence hypothesis contrast tests and df of the LR statistic are included. Adjusted ORs (aORs) in a multivariate logistic model as well as their 95%CIs appear in the last column of Table 2.

Basal reference categories are provided at the foot of the table. It may be noted that except for the 'presence of cattle' and 'house with outdoor lighting', being aged ⩽12 years, 'permanent openings in the house structure', 'usual sleeping place' and 'use of protecting net' were significantly associated with bite history.

Risk factors for having a history of bat bites in the last 30 days (bitten in the last month)

A total of 718 subjects reported the date on which they were last bitten. Of these, 50.4% (362) had been bitten in the last 30 days. Logistic regression of the variable 'history of bat bite in the last 30 days' with the factors studied above showed that the group at highest risk concerned those aged between 13 and 19 years (aOR 1.5, 95%CI 1.01–2.11), while protective bed net use (aOR 1.6, 95%CI 1.10–2.0) maintained its statistical significance.

DISCUSSION

This study reveals that two in every 10 interviewed people had been bitten in the last year, and that half had been bitten in the last month. Being aged ⩽12 years, dwelling conditions, usual sleeping place and not using a protective bed net were associated with a higher probability of having a history of bat bites in the previous year.

This study has certain limitations. First, the sample distribution of age and sex could seem highly distorted with respect to those aged <15 years and those older; however, it must be remembered that the vaccination campaign is carried out at a fixed date, and although the day of vaccination is communicated with at least 1 week's notice, the visit to each community only lasts at most 2 days, and thus it is possible that part of the community actively involved in hunting or fishing might be absent on the given day, particularly in the case of adults. Second, although we asked about bleeding wounds from bat bites, the data obtained may be affected by recall bias. However, they are in reasonable agreement with those reported in neighbouring countries. Third, we are aware that as this was an opportunistic sample of a little-known population recruited under the exceptional circumstances of an outbreak, it could yield results with biases that are difficult to quantify.

We found that one in every 10 persons reported having been bitten in the last month, and we consider that the short period involved means this figure is the most reliable; it is also in agreement with the Brazilian Amazon study, which reports 84 attacks per 100 person-years.[17]

The high rate of bat bites among inhabitants of this region coupled with the low incidence of rabies makes it difficult for these indigenous people to see a connection between the two events. This, together with the extremely difficult access to health services, may explain the low level of demand for medical care following a bat bite.

These data, combined with the local population density of 2 inhabitants/km^2 of land area,[18] have obvious implications when

TABLE 2 Association between history of bat bites within the previous year and risk factors

Variable	LR (df)	*P* value	Crude OR (95%CI)*	Adjusted OR (95%CI)
Sex	1.6 (1)	0.207	1.11 (0.94–1.31)	1.16 (0.97–1.39)
Age, years	106.9 (2)	⩽0.001		
13–19			0.57 (0.44–0.75)	0.39 (0.32–0.48)
⩾20			0.38 (0.31–0.46)	0.67 (0.50–0.90)
Presence of cattle	3.6 (1)	0.06	1.25 (0.99–1.58)	1.06 (0.83–1.31)
House with outdoor lighting	4.9 (1)	0.026	1.50 (1.04–2.18)	1.08 (0.78–1.45)
Use of protective bed net	18.9 (1)	0.01	1.45 (1.22–1.71)	1.25 (1.03–1.50)
Permanent openings in house structure	14.3 (1)	⩽0.001	1.62 (1.25–2.10)	1.49 (1.12–1.95)
Usual sleeping place	78.1 (1)	0.001	2.32 (1.93–2.78)	1.58 (1.21–2.06)

*Frequencies (*n*) and percentages (%) are described in Table 1. Reference categories were: male, aged ⩽12 years, outdoor lighting used during the night, no permanent openings in the structure of the house, bed as usual sleeping place, use of a protective bed net, and no presence of cattle.
LR = likelihood ratio; df = degrees of freedom; OR = odds ratio; CI = confidence interval.

it comes to planning prevention measures for bat bites. The specific world view held by these indigenous populations, such as the manner of integrating not only the concept of rabies as a disease but also the manner of combatting it, must be taken into consideration if we are to expect a massive positive response from the population. Although they involve different communities and different infectious pathologies, previous studies are testimony to this aspect.[17–20]

Factors associated with history of bat bites in the previous year show that there is a need to talk with the communities to help them to understand the need for and use of protective bed nets, as well as other protective measures such as blocking the permanent openings in the house structure whenever possible.[21] In addition, the reported considerable mobility between communities or countries needs to be taken into account in future bat bite prevention measures and vaccination campaigns.

The dispersion of the different communities, the cold chain needed for the conservation of vaccines, the need for a trained person to perform the vaccination and all of the other steps involved in the process must be considered in a setting of extreme poverty.[21] The number of persons bitten in the last year and the fact that the majority of attacks were concentrated in the last month would seem to advise against the use of a classical post-exposure vaccination scheme.[22] The scheme for a pre-exposure vaccination needs to be considered in the context of already existing general vaccination campaigns, with the use of a prior blanket strategy such as the one currently underway.[23] Finally, the application of risk models to study the movement of rabies in the Amazon communities could help optimise vaccination resources in populations at risk.[24]

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Objectif : Nous avons caractérisé les facteurs de risque des morsures des chauves-souris hématophages afin de fournir des informations contribuant à la prévention de la rage en Equateur.

Schéma : Etude transversale reposant sur les interviews de 3518 habitants, chez lesquels deux séries de variables ont été produites : caractéristiques des agressions par les chauves-souris hématophages chez des humains au cours de l'année précédente et facteurs de risque de morsures. Les données ont été analysées au moyen de modèles de régression logistique multivariée, avec comme variable de réponse un antécédent de morsure de chauves-souris au cours de l'année précédente.

Résultats : Parmi les 723 participants (20,6% ; IC95% 19,3–21,9) qui ont déclaré avoir subi des morsures de chauves-souris hématophages au cours de la dernière année, 50,4% avaient subi des morsures au cours du dernier mois, ce qui représente un taux d'incidence de 10,4% par mois (IC95% 9,6–11,6). Le fait de dormir sur le sol ou dans un hamac (OR ajusté [ORa] 1,58 ; IC95% 1,21–2,06), de ne pas utiliser un filet protecteur autour du lit (ORa 1,25 ; IC95% 1,03–1,50) et le fait de vivre dans une habitation comportant des ouvertures permanentes dans sa structure (ORa 1,49 ; IC95% 1,12–1,95), sont des éléments associés à une probabilité plus grande de morsures de chauves-souris. Le groupe le plus atteint a été celui âgé <12 ans (pour le groupe âgé de 13 à 19 ans, ORa 0,39 ; IC95% 0,32–0,48) ; pour le groupe âgé $\geqslant 20$ ans, ORa 0,67 ; IC95% 0,50–0,90).

Conclusions : Une prévention primaire basée sur une vaccination avant exposition pourrait être justifiable vu la forte dispersion de la population et l'incidence élevée des morsures. Les collectivités devraient veiller à augmenter l'utilisation de mesures secondaires de protection et à mettre des barrières dans les ouvertures permanentes des structures des habitations.

Objetivo: Caracterizar los factores de riesgo para las mordeduras de murciélagos hematófagos como contribución a la prevención de la rabia selvática en Ecuador.
Diseño: Estudio transversal basado en una encuesta aplicada a 3518 habitantes, donde se generaron dos conjuntos de variables: características del ataque de los vampiros a los humanos en el año previo a la encuesta y factores de riesgo asociados al mismo. Los datos fueron analizados usando modelos multivariantes siendo la variable respuesta haber sido mordido por el murciélago en el último año.
Resultados: Los participantes que declararon haber sido mordidos por vampiros en el último año fueron 723 (20,6%; IC95% 19,3–21,9) y en el último mes fue el 50,4% de ellos; la tasa de incidencia fue 10,4% por mes (IC95% 9,6–11,6). Dormir en el suelo o hamaca (OR ajustada [ORa] 1,58; IC95% 1,21–2,06), no usar red protectora alrededor de la cama—toldo (ORa 1,25; IC95% 1,03–1,50) y vivir en una vivienda con aperturas permanentes en su estructura (ORa 1,49; IC95% 1,12–1,95) se asociaron a una alta probabilidad de mordedura. El grupo de edad más afectado fueron los $<$12 años (edad 13 a 19 años, ORa 0,39; IC95% 0,32–0,48; $\geqslant$20 años ORa 0,67; IC95% 0,50–0,90).
Conclusiones: La prevención primaria basada en la vacunación antirábica con esquema pre-exposición debería ser analizada dada la alta tasa de incidencia y la gran dispersión de esta población. Como medida secundaria se debería trabajar junto a las comunidades para incrementar el uso de toldos y colocar barreras en las aperturas de las casas.

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e-ISSN 2220-8372
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