Urban epizootic of rabies in Mexico: epidemiology and impact of animal bite injuries*

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From 1 July 1987 to 31 December 1988, a total of 317 animals (91% of which were dogs) were confirmed to have rabies in Hermosillo, Mexico. The median age of rabid dogs was 1 year, 69% were male, and 98% were owned. The epizootic started in the southern areas of the city, rapidly involved the entire city, and persisted mainly in lower socioeconomic status areas. The area of the city and mean household size were significant predictor variables for the population density of rabid dogs around household clusters (Poisson linear regression, P <0.001 and P = 0.03, resp.).

Approximately 2.5% of city residents were bitten by dogs in 1987, with the rate of reported dog bite injuries being positively correlated with mean household size and the proportion of households that owned dogs. Visits to the city health centre for evaluation of possible exposures to rabies increased by 135% after the start of the epizootic; approximately 273 per 100 000 city residents were administered a full or partial course of rabies post-exposure prophylaxis in 1987. Children were at greatest risk for exposures to rabies, accounting for 60% of all reported animal bite injuries evaluated at the health centre. Also they were more likely than older persons to have received bite injuries to the head, face, and neck (odds ratio = 21.6, 95% confidence interval = 5.4, 186.5).

Introduction

In 1989, a total of 2776 human rabies deaths and 1 041 031 rabies post-exposure prophylaxis treatments were reported to WHO.¹ In developing countries, more than 200 persons undergo post-exposure prophylaxis for every human rabies case (1), often at substantial cost and sometimes with serious side-effects.

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Control of dog rabies is crucial, since almost all human rabies result from bites by rabid dogs.⁶ In several developing countries, dog rabies seems to be recurring in areas where it had once been controlled, possibly because of increasing population density and mobility of people and dogs,⁶ and the failure to maintain rabies control programmes. In most countries, dog rabies is an urban problem (2).⁷ Although the epidemiology of enzootic rabies in dogs has been amply described (3–11) reports of epizootics in dogs are relatively rare (12–14).

Animal bite injuries cause considerable morbidity and occasional mortality throughout the world. In areas where rabies is enzootic, such injuries also place an additional burden on health resources because of the frequent need to administer rabies post-exposure prophylaxis. We are unaware of any studies that have described the impact of animal bite injuries during a rabies epizootic. Accordingly, we report on the epidemiology of a major urban epizootic of rabies in Hermosillo, Mexico, and describe the impact of animal bite injuries during this outbreak.


Materials and methods

Hermosillo, the state capital of Sonora, is located in north-western Mexico, approximately 275 km south of the U.S. border. In 1987 the city’s estimated population was 431,000, and is rapidly growing. At the time of the epizootic, Hermosillo was divided into seven administrative health sectors. No cases of animal rabies were reported in Hermosillo from 1980 to 1984. In 1985 and 1986, respectively, 1 (2%) of 58 and 2 (4%) of 52 animals tested were positive for rabies. In the second half of 1987, however, 121 (74%) of 164 animals tested were positive for rabies, and the number of cases increased despite a mass vaccination programme.

Epidemiology

We initiated our investigation in January 1988. Records of all laboratory-confirmed cases of animal rabies (by direct fluorescence antibody (FA) examination of brain tissue) from 1 January 1985 to 28 February 1989 were obtained from the Hermosillo Centro de Salud. We collected information on characteristics of the animal and owner (if any) and the number of persons exposed by the animal.

Laboratory diagnosis of animal rabies

Samples of brain tissue from 70 suspect rabid dogs and cats examined by the Hermosillo Centro de Salud were also tested blind by the Centers for Disease Control (CDC) and the Arizona Department of Health Services. A series of monoclonal antibodies against rabies virus was used to compare three virus isolates from rabid dogs in Hermosillo with previous isolates from Mexico (15).

Household survey

A house-to-house survey of 1104 households was conducted in February 1988 to evaluate the owned dog population, rabies vaccination coverage, and other possible risk factors for rabies in dogs. The sampling was based on household clusters of the city developed by health officials for a previous childhood immunization survey. Each of the 550 clusters consisted of approximately 160 socioeconomically homogeneous households. We randomly selected 69 household clusters and, starting from a random point, surveyed 16 consecutive houses (approximately 10% of those in each cluster) for dog ownership, vaccination status, and household characteristics. Because many householders were reluctant to disclose their income, we used the mean household size and average monthly expenditure as surrogate measures of socioeconomic status (SES). The expenditure ranges we selected were too wide, resulting in a median monthly household expenditure that was similar in most sectors; as a measure of the median household expenditure in each sector we therefore used the proportion of households that reported expenditures below the overall median level.

Unrestricted dog survey

To estimate the population density of unrestricted dogs (dogs observed outside private property without obvious human supervision or physical restraint) in different areas of the city, we conducted a census of such dogs in two randomly selected household clusters in each sector of the city. In each cluster, we counted all unrestricted dogs that were observed from a vehicle being driven at approximately 15 km per hour through all streets within the cluster. Two counts (each on separate days) were made in each household cluster. The unrestricted dog population density per household cluster was defined as the average number of unrestricted dogs observed divided by the surface area of the cluster. The corresponding dog population density for each sector was estimated from the combined counts and surface in the two clusters for each sector.

Risk factors for rabies

A Poisson regression model was used to analyse the data from the household and unrestricted dog surveys for the relationship between the population density of rabid dogs and potential risk factors for rabies. For this purpose, the outcome variable was the number of rabid dogs within 1 km of a household cluster, while the sector of the city, median household monthly expenditures, mean household size, mean number of household dogs, and proportion of previously vaccinated household dogs (≥1 dose of antirabies vaccine) were the predictor variables. The logarithm of the rabid dog population density was used as the outcome variable in a generalized linear model that produced an asymptotically χ²-distributed test statistic (G²) (16). Among the 14 household clusters surveyed, the relationship between rabid dog population density and unrestricted dog population density was analysed using Spearman’s rank correlation. Because the results of the Poisson regression model indicated that the sector of the city accounted for most of the observed variation in the population density of rabid dogs around a household cluster, we also analysed the data by sector of the city. Spear-

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man’s rank correlation was used to analyse the relationship between the sector-specific attack rate of rabies (number of rabid dogs reported during the epizootic divided by the estimated number of owned dogs in that sector), the rate of reported dog bite injuries, and certain parameters related to SES and dog ecology. The number of months over which a sector had reported rabies was taken as a surrogate measure of the persistence of transmission.

**Animal bite injuries during the epizootic**

To examine trends in reported animal bite injuries, we abstracted the medical records of patients evaluated at the clinic that treats most persons who seek medical care for animal bites (Hermosillo Centro de Salud). For each month between 1 January and 31 December 1987, we randomly selected 15% of patient’s records and abstracted data on patients and the animals to which they had been exposed. A true exposure to rabies was defined as a bite or contamination of a person’s mucous membranes or open wounds with saliva from a laboratory-confirmed or clinically rabid animal.

**Statistical methods**

In addition to the Poisson linear regression and Spearman’s rank correlation, the following statistical tests were performed: a $\chi^2$ test to compare proportions; a Wilcoxon rank sum test to compare group means of nonparametric data; and an exact method (17) for calculating 95% confidence intervals (CI) for odds ratios (OR).

**Results**

**Epidemiology of the epizootic**

The epizootic started in July or August 1987, peaked in November 1987, remained at a high level from December to May 1988, and started to decrease in June 1988 (Fig. 1). Between 1 January 1987 and 30 June 1987, only 1 (3%) of 33 animals tested for rabies was positive, but during the second half of 1987, 121 (74%) of 164 animals tested positive. From 1 July 1987 to 31 December 1988, 317 (65%) of 489 animals tested positive: 90.5% (287) of these were dogs, 8.5% (27) cats, and 1% other animals. The epizootic apparently began in the southern part of Hermosillo, where 9 of the first 10 cases occurred (sectors V and VII, see Fig. 2). The outbreak spread rapidly northward, involved most of the city by November 1987, and persisted in several areas, especially in the south. No cases of human rabies were reported during the epizootic.
The median age of rabid dogs was 1 year (range: 1 month to 20 years); 8% were aged <3 months; and 44% were <1 year (Fig. 3). A total of 69% of the dogs were male and 98% were owned. Rabid dogs bit a median of one person (range: 0–13 persons). The median age of rabid cats was 2 years (range: 5 months to 7 years), of which 76% were male and 92% were owned. Rabid cats bit a median of two persons (range: 0–6 persons). Information on the rabies vaccination status was available for 247 of these rabid dogs; 74 of the owners (30%) stated that their dog had previously been vaccinated for rabies. None of the rabid cats had previously been vaccinated.

**Laboratory diagnosis of animal rabies**

Brain tissue samples from 69 dogs and 3 cats were examined in Hermosillo and the USA. Compared with the FA assay conducted in the USA, the sensitivity and specificity of the assay performed in Hermosillo were 87.0% and 37.5%, respectively (Table 1). A total of 76% of the results from the two U.S. laboratories agreed with those found in Hermosillo. Although the number of specimens tested increased during the epizootic, the proportions that were positive paralleled the epidemic curve (Fig. 1). Three virus isolates from rabid dogs exhibited monoclonal antibody reaction patterns identical to the dominant ecotype found in rabid dogs in the Americas from Argentina to the USA (13).

**Surveys of households and unrestricted dogs**

Of the 1104 households surveyed, 912 (83%) agreed to be interviewed. Some of the data collected are shown in Table 2, according to the sector of the city and attack rate of rabies in dogs. Approximately 460 000 persons and 56 700 resident-owned dogs (ratio, 8:1) lived in Hermosillo at the time of the survey. The mean household size was 5.2 persons, and 47% of households owned dogs.

In the households surveyed, 111 persons reported having been bitten by a dog during the previous 12 months. Extrapolation of the proportion of persons bitten to the entire city's population indicated that approximately 2.5% (2497 per 100 000 persons) of the residents of Hermosillo had been bitten by dogs in 1987. There was no significant difference in the risk of dog bite injuries between households that owned dogs (13%) and those that did not (10%) (OR = 1.3; 95% CI = 0.8, 2.0).

A total of 588 dogs were owned by the households surveyed. The median age of household dogs was 2 years (range: 1 month to 15 years); 8% were <3 months of age; and 27% were <1 year (Fig. 3). Owned dogs were significantly older than rabid dogs (the ages of dogs with negative rabies tests were not available) (Wilcoxon rank sum test, $P = 1 \times 10^{-4}$). Of the owned dogs, 65% were male, 89% were originally acquired inside the city, and 11% were acquired outside. The vaccination rates of household dogs varied greatly according to the sector of the city (Table 2). A total of 75% of vaccination histories were documented by a vaccination certificate. Among dogs aged ≥3 months, 77% had received one or more vaccinations and 68% were currently vaccinated.

![Fig. 2. Geographical distribution of rabid dogs in Hermosillo, by sectors of the city, September 1987 to July 1988.](image)

![Fig. 3. Age distributions of rabid dogs and of owned dogs identified through the household survey.](image)
Table 1: Comparison of the results of rabies fluorescence antibody tests performed in Hermosillo and at two reference laboratories

<table>
<thead>
<tr>
<th>Hermosillo</th>
<th>Reference laboratories</th>
<th>No. positive</th>
<th>No. negative</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. positive</td>
<td>No. negative</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>47</td>
<td>10</td>
<td>57</td>
</tr>
<tr>
<td>No. positive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. negative</td>
<td></td>
<td>7</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>54</td>
<td>16</td>
<td>70</td>
</tr>
</tbody>
</table>

*a* Hermosillo versus the reference laboratories: sensitivity = 87.0%; positive predictive value = 82.5%; specificity = 37.5%; and negative predictive value = 46.2%.

*b* Centers for Disease Control, Atlanta, GA, USA; and Arizona Department of Health Services, Tucson Regional Laboratory, Tucson, AZ, USA.

An average of five unrestricted dogs (range 0–10 dogs) were counted within the 14 household clusters surveyed; the unrestricted dog density was generally greater in city sectors with low SES indicators (Table 2).

**Risk factors for rabies**

A Poisson regression analysis revealed that the sector of the city was the most useful variable for predicting the population density of rabid dogs (Table 3). When both this variable and mean household expenditure were excluded from the model, mean household size was still significantly associated with the population density of rabid dogs. However, the best model that did not include sector of the city failed to explain adequately extra-Poisson variation, i.e., the unexplained variation was greater than would be expected from a random sampling of a Poisson random variable ($G^2 = 102.4; 63$ degrees of freedom (df); $P = 0.0012$). In contrast, inclusion of sector of the city in the regression model provided a good fit ($G^2 = 62.0; 62$ df; $P = 0.476$).

Grouping the data by sector of the city revealed several significant positive correlations (Table 4). The rate of reported dog bite injuries was statistically correlated with the number of months for which rabid dogs were reported, the mean household size, and the proportion of households that owned dogs. Dog ownership was positively correlated with mean household size and mean of household expenditure. In addition, the proportion of previously vaccinated dogs was negatively correlated with the unrestricted dog population density. Although there was no correlation between the sector-specific attack rate of rabid dogs and unrestricted dog density, Spearman’s rank

Table 2: Selected characteristics of surveyed households and unrestricted dog population density, by sector of the city

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Sector:</th>
<th>V</th>
<th>II</th>
<th>VI</th>
<th>IV</th>
<th>I</th>
<th>VII</th>
<th>III</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attack rate of rabies in dogs during the epizootic (per 100 000 owned dogs)</td>
<td></td>
<td>829</td>
<td>621</td>
<td>529</td>
<td>497</td>
<td>345</td>
<td>296</td>
<td>232</td>
<td>499</td>
</tr>
<tr>
<td>No. of months for which rabid dogs were reported in sector*</td>
<td></td>
<td>14</td>
<td>10</td>
<td>6</td>
<td>11</td>
<td>8</td>
<td>10</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Mean household size (No. of persons)</td>
<td></td>
<td>5.4</td>
<td>5.2</td>
<td>4.5</td>
<td>5.5</td>
<td>5.0</td>
<td>5.1</td>
<td>5.4</td>
<td>5.2</td>
</tr>
<tr>
<td>Households with monthly expenditures below the median level (%)</td>
<td></td>
<td>49</td>
<td>32</td>
<td>10</td>
<td>46</td>
<td>29</td>
<td>18</td>
<td>36</td>
<td>33</td>
</tr>
<tr>
<td>Households owning dogs (%)</td>
<td></td>
<td>59</td>
<td>44</td>
<td>40</td>
<td>60</td>
<td>32</td>
<td>43</td>
<td>46</td>
<td>47</td>
</tr>
<tr>
<td>Rate of dog bite injuries (per 100 000 per year)</td>
<td></td>
<td>2691</td>
<td>2680</td>
<td>1052</td>
<td>4677</td>
<td>982</td>
<td>2492</td>
<td>1801</td>
<td>2497</td>
</tr>
<tr>
<td>Previously vaccinated dogs (%)</td>
<td></td>
<td>66</td>
<td>68</td>
<td>86</td>
<td>61</td>
<td>56</td>
<td>77</td>
<td>64</td>
<td>68</td>
</tr>
<tr>
<td>Currently vaccinated dogs (%)</td>
<td></td>
<td>64</td>
<td>56</td>
<td>81</td>
<td>51</td>
<td>37</td>
<td>66</td>
<td>64</td>
<td>60</td>
</tr>
<tr>
<td>Average number of unrestricted dogs (per household cluster)</td>
<td></td>
<td>4.5</td>
<td>7.8</td>
<td>0</td>
<td>10</td>
<td>7.0</td>
<td>3.8</td>
<td>6.5</td>
<td>5.3</td>
</tr>
<tr>
<td>Unrestricted dog population density (No./km²)</td>
<td></td>
<td>60</td>
<td>82</td>
<td>0</td>
<td>110</td>
<td>86</td>
<td>38</td>
<td>144</td>
<td>66</td>
</tr>
</tbody>
</table>

*a* Sectors are shown in decreasing order of the attack rate of dog rabies.

*b* For the 14-month period July 1987 to August 1988; sector locations of rabid dogs diagnosed between September 1988 and December 1988 were not available.
Table 3: Poisson regression analysis of rabid dog population density around household clusters and selected variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Single variable model</th>
<th></th>
<th>Model adjusted for:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G^2</td>
<td>df^a</td>
<td>P-value</td>
<td>Sector of city</td>
<td>G^2</td>
</tr>
<tr>
<td>Sector of city</td>
<td>71.1</td>
<td>6</td>
<td>&lt;0.001</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Median monthly household expenditures</td>
<td>23.7</td>
<td>3</td>
<td>&lt;0.001</td>
<td>3.7</td>
<td>3</td>
</tr>
<tr>
<td>Mean household size</td>
<td>6.2</td>
<td>1</td>
<td>0.015</td>
<td>5.0</td>
<td>1</td>
</tr>
<tr>
<td>Mean number of household dogs</td>
<td>0.8</td>
<td>1</td>
<td>0.353</td>
<td>&lt;0.05</td>
<td>1</td>
</tr>
<tr>
<td>% of previously vaccinated dogs</td>
<td>1.9</td>
<td>1</td>
<td>0.167</td>
<td>0.1</td>
<td>1</td>
</tr>
</tbody>
</table>

^a df = degrees of freedom.

correlation for the rabid dog population density around household clusters and the number of unrestricted dogs in the 14 household clusters surveyed was almost statistically significant (Spearman's rank correlation coefficient = 0.52; 12 df; P = 0.07).

**Animal bite injuries during the epizootic**

In 1987, a total of 2086 persons (453 per 100,000 persons per year) were evaluated at the Centro de Salud for possible exposures to rabies. Patient visits increased by 135% after the epizootic started, from a mean of 104 persons per month during the first half of 1987 to 244 during the second half (Fig. 1). The number of patient visits increased sharply in September 1987, approximately 2 months after the start of the epizootic, and paralleled the epidemic curve.

A review of the medical records of a sample of 312 patients examined for possible exposures to rabies revealed that most patients were children aged

Table 4: Spearman's rank correlation matrix for selected variables grouped by sector of the city

<table>
<thead>
<tr>
<th>Variable</th>
<th>AR</th>
<th>BITES</th>
<th>MONTH</th>
<th>HHSIZ</th>
<th>HHEXP</th>
<th>HHDOG</th>
<th>VACC</th>
<th>DENS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attack rate of rabid dogs during epizootic (AR)</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of dog bite injuries (BITES)</td>
<td>0.429</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of months rabid dogs were reported (MONTH)</td>
<td>0.396</td>
<td>0.919^a</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean household size (HHSIZ)</td>
<td>0.036</td>
<td>0.811^a</td>
<td>0.955^a</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of households with monthly expenditures below the median level (HHEXP)</td>
<td>0.286</td>
<td>0.714</td>
<td>0.793^a</td>
<td>0.901^a</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of households that owned dogs (HHDOG)</td>
<td>0.214</td>
<td>0.893^a</td>
<td>0.811^a</td>
<td>0.955^a</td>
<td>0.857^a</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of previously vaccinated dogs (VACC)</td>
<td>0.250</td>
<td>-0.036</td>
<td>-0.162</td>
<td>-0.451</td>
<td>-0.536</td>
<td>-0.214</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Unrestricted dog population density (DENS)</td>
<td>-0.429</td>
<td>0.143</td>
<td>0.144</td>
<td>0.648</td>
<td>0.571</td>
<td>0.429</td>
<td>-0.821^a</td>
<td>1.000</td>
</tr>
</tbody>
</table>

^a Indicates a statistically significant correlation coefficient (P ≤ 0.05 if coefficient > 0.786 or < -0.786).
<13 years (median age, 9 years; range, <1–84 years). Children accounted for 60%, teenagers for 13%, and adults (> 19 years old) for 27% of all patient visits; 53% of patients were male. A total of 93% of the patients who were evaluated had true exposures to confirmed or clinically rabid animals; 98% of the patients with true exposures had been bitten, and 2% had non-bite exposures. Altogether, 89% of the animals concerned were dogs, 9% were cats, and 2% were other animals. Because the characteristics of the bite injuries inflicted by dogs or cats were similar, incidents involving these animals were combined in subsequent analyses. Of the animals responsible for human exposures, 54% were healthy after quarantine, 23% were tested and confirmed rabid, 21% had escaped or died and were not tested, and 1% were tested and negative. A total of 65% of patients were bitten at a residence, 32% while in public areas (mostly streets), 2% at their workplace, and 1% at other locations.

Overall, 38% of the patients evaluated had completed a full course of post-exposure prophylaxis (14–16 doses of suckling mouse brain vaccine), 22% had received a partial course (1–13 doses), and 40% did not require prophylaxis. Extrapolating the rate of post-exposure prophylaxis to the city’s population indicates that approximately 273 per 100,000 residents of Hermosillo had received a full or partial course of prophylaxis in 1987.

The location of bites to the body differed between children and teenagers and adults. A total of 30% of children were bitten on the head, face, or neck, compared with only 2% of teenagers and adults (OR = 21.6, 95% CI = 5.4, 186.5) (Table 5). Multiple bite injuries were exhibited by 11% of children and 9% of teenagers and adults.

### Table 5: Distribution of the sites of animal bite injuries for children as well as teenagers and adults evaluated at the Hermosillo Centro de Salud, 1 January to 31 December 1987

<table>
<thead>
<tr>
<th>Site of injury</th>
<th>No. of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Children</td>
</tr>
<tr>
<td>Head, face, or neck</td>
<td>47 (30a)</td>
</tr>
<tr>
<td>Upper extremities</td>
<td>52 (33)</td>
</tr>
<tr>
<td>Trunk</td>
<td>16 (10)</td>
</tr>
<tr>
<td>Lower extremities</td>
<td>59 (38)</td>
</tr>
</tbody>
</table>

* Figures in parentheses indicate the % of all persons in the age group concerned (157 children and 103 teenagers and adults). Column totals may be greater than the number of persons in an age group because some patients were bitten at more than one site.

** Figures in italics are the % of the total number of individuals (260).

### Discussion

#### Epidemiology of the epizootic

The risk of rabies in dogs appears to be greater in lower SES areas. In Hermosillo, although one surrogate measure of SES, lower monthly household expenditures, was not associated with the number of rabid dogs around household clusters, an association did exist for mean household size. When data were grouped by sector of the city, there was no significant correlation between the attack rate of rabies and various factors associated with SES and unrestricted dogs. However, the attack rates of rabies in lower SES areas were probably underestimated relative to those in higher SES areas, because fewer specimens were submitted for analysis in the former areas.

The cases of rabid dogs reported before July 1987 indicated that a low level of rabies had been present in Hermosillo for several years before the epizootic. Although its origin was unclear, the epizootic may have resulted when the dog population density increased and herd immunity was low. The rapid progression of the epizootic could have arisen because of the negative correlation between the proportion of previously vaccinated dogs and the population density of unrestricted dogs. This suggests that the risk of a rabies epizootic is compounded by high population densities of unrestricted dogs in areas where vaccination coverage is low. Although the entire city was eventually affected by the outbreak, it appeared to have started and was more persistent in lower SES areas. For example, the number of months over which rabid dogs were reported was positively correlated with household size and the proportion of households with low monthly expenditures. Previous studies have found that lower SES areas in cities have greater population densities of unrestricted dogs (18), but we were not able to confirm this for Hermosillo.

Young dogs are probably more susceptible to rabies than adult dogs (19), and two other studies of epizootics have reported a large proportion of young rabid dogs (3, 7). The large proportion of young dogs in Hermosillo suggests that susceptible animals are constantly being added to the community. The similar proportion of rabid and household dogs that were male does not suggest that gender was a risk factor for rabies, but rather reflects the preference of many communities for male dogs. More than 98% of confirmed rabid dogs in Hermosillo were owned; this is not unusual in developing countries (11, 20).

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*a* See footnote d, p. 616.

*b* See footnote c, p. 615.
Our attempt to correlate social and ecological factors with the risk of rabies may have been hampered by the performance characteristics of the FA test in Hermosillo. Unfortunately, we were unable to confirm all the FA results in Hermosillo because split samples were unavailable for most of the animals tested.

**Laboratory diagnosis of animal rabies**

Sensitive and specific laboratory diagnosis of animal rabies is important for the evaluation of patients bitten by suspected rabid animals. At the Centro de Salud there was a tendency to commence and continue administration of rabies post-exposure prophylaxis, despite a negative FA test, if the animal’s clinical signs were compatible with rabies. This practice, and the high immunogenicity of the vaccine used, may explain the absence of human rabies during the epizootic. We were not able to determine the frequency of adverse reactions after rabies vaccination in Hermosillo; however, in 1967 the rate of neurological reactions associated with suckling mouse brain vaccine in Latin America was 1 per 7865 persons vaccinated (21).

**Household surveys and rabies control programmes**

Surveys should be conducted before implementing a control programme in order to obtain data on target populations and community attitudes, since ecological characteristics can vary among communities (22, 23). In Hermosillo, we estimated the number of unvaccinated dogs aged ≥3 months in each sector to determine the area-specific target populations and to plan the distribution of vaccination clinics.

Surveys can also provide important information on the attitudes of communities to rabies and dogs. For example, most owners of unvaccinated dogs in Hermosillo wanted them to be vaccinated; however, 13% of such owners could not bring their dog to the vaccination clinics, and thus, would not be reached by clinic-based programmes. Surveys also disseminate information on rabies and publicize upcoming vaccination programmes. Moreover, surveys of large communities do not require a great deal of resources — our citywide survey of 912 households was completed by 10 interviewers in 3 days.

**Animal bite injuries during the epizootic**

In themselves, animal bite injuries are important causes of morbidity (24) and also because of the associated risk of rabies. The rate of use of rabies post-exposure prophylaxis in Hermosillo (273 per 100 000), not including patients who were treated by private physicians, was approximately 58 times that reported in the USA for 1980–81 (4.7 per 100 000) (25). The annual rates of reported dog bite injuries in urban areas of the USA range from 71 to 840 per 100 000 persons (26–30); in Hermosillo the rate was approximately three times greater than the highest rate reported in the USA. Since 2.5% of Hermosillo residents were bitten annually by dogs, only 16% (404/2497) of all dog bite injuries were evaluated at the Centro de Salud in 1987.

In agreement with other reports (26–33) we found that children are most likely to be bitten by animals; children are especially at risk of rabies because most of the bite injuries they receive are not reported to health professionals (26, 31). Children were also more likely to be bitten on the head, face, and neck; bites in these areas are more likely to result in rabies (34). In contrast to other studies that have reported a higher proportion of male patients (27, 28, 30, 31, 33, 35), we found a similar proportion of male and female patients. Educational programmes and other interventions for preventing animal bite injuries and rabies should be targeted towards young children and residents of lower SES areas.

An increased risk of dog bite injuries and human rabies in the lower SES areas of developing countries has been reported (36). In Hermosillo, the rate of dog bite injuries increased with mean household size, a surrogate of SES. Although the rate of such injuries was positively correlated with the prevalence of dog ownership, ownership of a dog per se was not a risk factor for dog bite injuries — many people were bitten by dogs that they did not own. In addition, almost a third of patients were bitten while in public areas. Therefore, implementation of laws restricting dogs to private property, although probably not practical or socially acceptable in some areas, could prevent many dog bite injuries and exposures to rabies.

Many patients in Hermosillo were bitten by cats. Although dogs are the major reservoir of rabies in developing countries, cats may be of increasing importance in this respect, especially if immunization programmes target only dogs. In the USA rabid cats account for a greater number of rabies post-exposure prophylaxes than rabid dogs and are more likely than rabid dogs to bite people (37).

Our findings illustrate the various relationships between socioeconomic factors, animal ecology, and rabies transmission in a community, and the importance of rabies surveillance and control programmes that take these parameters into account. Rabies epi-

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zootics still have a substantial impact on the public health resources of many developing countries. Moreover, animal bite injuries and the associated risk of rabies exert a disproportionate health burden upon children and residents of lower SES areas.

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Résumé

Epizootie urbaine de rage au Mexique: épidémiologie de la maladie et conséquences des lésions par morsure

La quasi-totalité des décès humains dus à la rage sont consécutifs à une morsure par un chien enragé. Alors qu'on connaît bien l'épidémiologie de la rage enzootique chez le chien, les épizooties canines sont plus rarement décrites. Outre le risque de rage, les lésions par morsure entraînent une morbidité considérable et parfois le décès de la victime, et cela dans le monde entier. Cet article rapporte l'épidémiologie d'une vaste épizootie urbaine de rage à Hermosillo, au Mexique, et décrit les conséquences des lésions par morsure au cours de cette épizootie.

Du 1er juillet 1987 au 31 décembre 1988, 317 animaux, dont 91% de chiens, ont été atteints de rage confirmée à Hermosillo. L'âge moyen des chiens enragés était d'un an, 69% étaient des chiens mâles et 98% avaient un maître. L'épizootie a commencé dans les quartiers méridionaux de la ville et s'est rapidement étendue à la ville tout entière, s'attardant principalement dans les zones défavorisées. L'analyse des données d'une enquête portant sur 912 ménages (sondage par grappes) et d'une enquête à l'échelle de la ville sur les chiens laissés en liberté, a montré que la taille de la ville et la taille moyenne des ménages étaient des variables prédictives statistiquement significatives pour la densité de population de chiens enragés autour des grappes de ménages considérées (régression linéaire de Poisson, $P < 0.001$ et $P < 0.03$, respectivement). Le risque de rage chez les chiens était plus élevé dans les quartiers économiquement défavorisés, où l'on comptait une forte densité de population de chiens laissés en liberté et un faible taux de vaccination antirabique. L'extrapolation des données de l'enquête sur les ménages a montré qu'environ 2,5% des habitants de la ville avaient été mordus par un chien en 1987. Dans un secteur donné, le taux de lésions par morsure de chien était positivement corrélé avec la taille moyenne des ménages et avec la proportion de ménages possédant des chiens. Il n'y avait aucune différence significative de risque de morsure entre les ménages possédant des chiens (13%) et les autres (10%) (odds ratio = 1,3, intervalle de confiance à 95% (IC) = 0,8–2,0).

L'examen des dossiers médicaux du centre de santé principal montre que le nombre de visites motivées par un risque d'exposition à la rage a augmenté de 135% après le début de l'épizootie et que la proportion d'habitants de la ville ayant reçu un traitement antirabique partiel ou complet après morsure s'est élevée à environ 273 pour 100 000 en 1987. Les sujets à risque maximal d'exposition à la rage étaient les enfants, qui totalisaient 60% de l'ensemble des cas de morsure examinés au centre de soins, et qui risquaient davantage que les adultes d'être mordus à la tête, au visage et au cou (odds ratio = 21,6; IC 95% = 5,4–186,5).

Les enquêtes dans les ménages et les enquêtes sur les chiens laissés en liberté sont utiles dans le cadre des activités de lutte contre la rage car elles donnent des estimations de la couverture vaccinale et des populations cibles pour la vaccination, ainsi qu'une information à l'échelle de la communauté sur l'épidémiologie et l'épidémiologie de la rage animale. Des programmes éducatifs et autres interventions destinés à prévenir les morsures d'animal et la rage devront être orientés vers les groupes à haut risque tels que les jeunes enfants et les habitants des zones défavorisées. Une législation socialement et culturellement acceptable pour essayer de résoudre le problème des chiens laissés en liberté pourrait aider à prévenir à la fois les lésions par morsure et l'exposition à la rage.

References


