Epidemic Dengue and Dengue Hemorrhagic Fever at the Texas–Mexico Border: Results of a Household-based Seroepidemiologic Survey, December 2005

Mary M. Ramos,* Hamish Mohammed, Emily Zielinski-Gutierrez, Mary H. Hayden, Jose Luis Robles Lopez, Marta Fournier, Alfredo Rodriguez Trujillo, Roy Burton, Joan M. Brunkard, Luis Anaya-Lopez, Allison Abell Banicki, Pablo Kuri Morales, Brian Smith, Jorge L. Muñoz, Stephen H. Waterman, and The Dengue Serosurvey Working Group†

Dengue Branch, Division of Vector-Borne Infectious Disease, Centers for Disease Control and Prevention, Atlanta, Georgia; Route of Global Migration and Quarantine, National Center for Preparedness, Detection, and Control of Infectious Disease, Centers for Disease Control and Prevention, Atlanta, Georgia

Abstract. A dengue-2 epidemic causing dengue hemorrhagic fever (DHF) occurred in the contiguous border cities of Matamoros, Tamaulipas (Mexico), and Brownsville, TX, in 2005. In December, we conducted a household-based epidemiologic survey to determine the incidence and seroprevalence of dengue infection among Matamoros and Brownsville residents and to identify risk factors associated with infection. Antibodies to dengue were measured in 273 individuals. The estimated incidence of recent dengue infection was 32% and 4% among Matamoros and Brownsville participants, respectively. The estimated prevalence of past dengue infection was 77% and 39% among Matamoros and Brownsville participants, respectively. The Breteau index was 28 in Matamoros and 16 in Brownsville, reflecting an abundant winter population of Aedes mosquitoes. Discarded waste tires and buckets were the two largest categories of infested containers found in both cities. Our results underscore the risk for epidemic dengue and DHF in the Texas–Mexico border region.

INTRODUCTION

Dengue is an acute infection caused by the four dengue virus serotypes (DENV-1, DENV-2, DENV-3, and DENV-4) and transmitted by Aedes species mosquitoes. Most DENV infections cause no symptoms or mild illness, but any of the four serotypes can cause dengue fever or the potentially fatal clinical syndrome of dengue hemorrhagic fever (DHF). Although the mechanisms for the development of DHF and severe disease manifestations are not fully understood, a major risk factor for DHF is secondary infection with another serotype.1–3 Viral strain and host factors also may influence the development of DHF and severe disease manifestations.4–7

In the fall of 2005, Texas health officials reported a 31-year old woman from Cameron County, in southern Texas, with autochthonously acquired DHF.8 This was only the second case of locally acquired DHF ever reported in Texas and the first in a native of the Texas–Mexico border region.5 By November 2005, two additional autochthonous cases of dengue fever were reported in Cameron County, along with 22 persons with dengue fever who had traveled to Mexico (J. Schuermann and others, unpublished data). This was the largest outbreak of dengue reported among Texas residents since 1999.

The 2005 South Texas outbreak was linked to a dengue epidemic just south of the Texas–Mexico border, in the Mexican state of Tamaulipas, which has a population of 3.2 million (Figure 1). In 2005, 7,062 dengue cases were reported in Tamaulipas, including 1,832 (26%) cases classified as DHF. DENV-2 was the predominant serotype in Tamaulipas (i.e., 27 of 28 viral isolates were DENV-2, 1 was DENV-1; Panorama Epidemiológico del Dengue y Dengue Hemorrágico, http://www.cenave.gob.mx/dengue/panorama/Panoramasemana52.pdf) The DENV-2 virus was a southeast Asian strain previously associated with DHF in the Americas.4,10

In December 2005, 2 months after the Tamaulipas dengue epidemic peaked, we conducted a household-based seroepidemiologic survey in the contiguous border cities of Matamoros, Tamaulipas (population 462,157), and Brownsville, TX (population 167,493). The objectives were to determine the incidence of recent dengue infection among Matamoros and Brownsville residents and the seroprevalence of antibodies to dengue. We measured the presence of Aedes species mosquitoes and identified the containers serving as immature mosquito habitats in both cities. We further sought to identify risk factors for dengue infection in each city.

MATERIALS AND METHODS

Survey. We used a two-stage cluster survey design similar to that used by the World Health Organization (WHO) Expanded Program on Immunization to obtain a representative sample of households from Brownsville and Matamoros.11 Thirty census tracts from 2000 census data were systematically selected from each city after ordering by income to

* Address correspondence to Mary M. Ramos, Department of Pediatrics, University of New Mexico, 300 San Mateo Boulevard, NE, Suite 902, Albuquerque, NM 87108. E-mail: mramos@salud.unm.edu
† Other members of The Dengue Serosurvey Working Group include Carlos Moya-Rabelly (Mexico Section of the US–Mexico Border Health Commission), Carlos Alvarez-Lucas and Cualtemoc Mancha (Centro Nacional de Vigilancia Epidemiológica y Control de Enfermedades), Luis Fernando Garza Frausto, Ernesto Lavin Hernandez, and Norma Alicia Villarreal Reyes (Servicios de Salud de Tamaulipas), Victor Garcia Fuentes and Oscar Ramirez Contreras (Jurisdicción Sanitaria No. III de Matamoros), Joshua Ramirez (City of Brownsville Public Health Department), Mark Beatty (Pediatric Dengue Vaccine Initiative), Rafael Moreno-Sanchez (University of Colorado), Iris Sosa, Sophie Wenzel, Brad Biggerstaff, and Miguel Escobedo (Centers for Disease Control and Prevention).
ELISA format microneutralization testing was performed on samples that tested positive for IgG antibody titers ≥ 1:2,560 to test for neutralizing IgG antibodies to DENV serotypes and to WNV and SLEV. Those with IgG titers > 1:2,560 were excluded from microneutralization testing because of greater potential for cross-reactivity among the flaviviruses.

Serologic evidence of recent dengue infection was defined by IgM antibodies ≥ 0.2 optical density (OD) or the presence of high-titered IgG antibodies > 1:40,960, consistent with a recent secondary infection. Evidence of any past dengue infection either recent or remote, was defined by the presence of IgM antibodies to dengue (≥ 0.2 OD) or IgG antibodies ≥ 1:40.

Analysis. Data were weighted to reflect probability of selection, taking into account the population and number of households per census track and size of household. Analysis was performed using SAS v.9.1 (SAS Institute, Cary, NC) software. Frequencies and crude and adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated. Variables found to be associated with dengue infection on univariate analysis (P ≤ 0.10), as well as covariates age, sex, and socioeconomic status (SES) as measured by census tract income data from the 2000 US and Mexico census, were included in the multivariate logistic regression models.

Ethical review. The investigation protocol was reviewed by the Human Subjects Coordinator at the National Center for Infectious Diseases, Centers for Disease Control and Prevention, and by the Centro Nacional de Vigilancia Epidemiológica y Control de Enfermedades de Mexico and determined to be an outbreak study and public health response that did not require further human subjects review. Blood samples (~4 mL) were collected from consenting participants. Informed consent of a parent or guardian was obtained before taking blood from a minor.

RESULTS

Survey. From December 5 through 10, 2005, 240 households in Matamoros were visited. Adult residents were home in 143 households; 111 (78%) households agreed to participate in the survey. From the 111 participating households, 132 serum samples were collected. From December 12 through 15, 2005, 346 households in Brownsville were visited. Adult residents were home in 161 households; 118 (73%) households agreed to participate in the survey, and 141 serum samples were collected.

One third (29%) of homes surveyed in Matamoros had air conditioning; in contrast, most (85%) homes surveyed in Brownsville had air conditioning (P < 0.05). Nearly two thirds of homes (65% in Matamoros and 61% in Brownsville) had screens on windows and doors, per the residents’ report. The mean lot size was smaller in Matamoros (307 m²) than in Brownsville (1070 m²; P < 0.05), reflecting its more dense urban environment. Forty-six percent of participants from each city reported having crossed the US–Mexico border in the preceding 3 months. Few Matamoros residents (13%) or Brownsville residents (21%) reported using insect repellent “often” or “always” when outdoors in the 3 months before the survey.

Entomology. During the residential surveys in Matamoros, we found larvae and pupae of Ae. aegypti mosquitoes; we did not find Ae. albopictus. In contrast, both Ae. aegypti and Ae. albopictus immature forms were collected in Brownsville. The Breteau index was 28 in Matamoros (Ae. aegypti only) versus 11 (Ae. aegypti only) and 16 (combined Ae. species) in Brownsville. Tires represented one third (32%) of the infested containers seen in Matamoros and a quarter (26%) of the infested containers identified in Brownsville, making up the largest single category of infested container in either site (Figure 2). Buckets were the second leading category of infested container for both cities.
Dengue serology. One third (32%) of Matamoros residents had serologic evidence of recent dengue infection, as did 4% of Brownsville residents (Table 1). Approximately one half (23 of 42) of the recent dengue infections in Matamoros were associated with high IgG antibody titers and thus seemed to be secondary infections. One third (2 of 6) of the recent dengue infections in Brownsville seemed to be secondary infections. Most (77%) Matamoros residents had serologic evidence of past dengue infection, as did 39% of Brownsville residents. Through microneutralization testing, we detected IgG antibodies to all four DENV serotypes among Matamoros residents and antibodies to DENV-1 and DENV-3 among Brownsville residents. No antibodies to WNV or SLEV were detected.

Few participants from 5 to 14 years old were enrolled from either city (Table 2). Among Matamoros residents at least 15 years old, the prevalence of past dengue infection varied between 71% and 78%. In contrast, the seroprevalence in Brownsville varied from a low of 14% among those 45–64 years old to 56% among those 25–44 years old.

Risk factor analysis—Matamoros. In Matamoros, those living with a head of household who cited source reduction methods (e.g., “cleaning up patios”) as important in dengue control were six times more likely to have serologic evidence of recent dengue infection than those living with heads of household who did not identify source reduction as useful in controlling dengue (Table 3). Those without air conditioning in the house were seven times more likely to have serologic evidence of past dengue infection than those with air conditioning (Table 3). Those who reported no or infrequent insect repellent use were twice as likely to have serologic evidence of past dengue infection than Matamoros residents who reported using repellent always or often.

Risk factor analysis—Brownsville. Among Brownsville residents, those with smaller lot size (less than the median size among those surveyed) were 15 times more likely to have serologic evidence of recent dengue infection than those with lot sizes greater than the median (Table 3). Those residents born outside of the United States were three times more likely to have serologic evidence of past infection than Brownsville residents who were native to the United States (Table 3).

Autochthonous dengue—Brownsville. Twenty-four Brownsville survey participants were born in the United States and reported never having traveled outside the United States. Of these 24 people, 6 (25%; 95% CI, 12–45%) were seropositive for antibodies to dengue, indicating past infection. One person had IgM antibodies only, four had IgG antibodies only, and one had both IgM and IgG antibodies.

TABLE 2
Serology results for seroepidemiologic survey by age and sex, Matamoros and Brownsville—December 2005

<table>
<thead>
<tr>
<th>Age group† (years)</th>
<th>Matamoros</th>
<th>Brownsville</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recent infection* (%)</td>
<td>Past infection† (%)</td>
</tr>
<tr>
<td>5–14</td>
<td>69.4</td>
<td>69.4</td>
</tr>
<tr>
<td>15–24</td>
<td>33.9</td>
<td>76.7</td>
</tr>
<tr>
<td>25–44</td>
<td>36.0</td>
<td>77.6</td>
</tr>
<tr>
<td>45–64</td>
<td>20.2</td>
<td>76.4</td>
</tr>
<tr>
<td>≥ 65</td>
<td>37.1</td>
<td>71.2</td>
</tr>
<tr>
<td>Sex§</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>35.3</td>
<td>81.1</td>
</tr>
<tr>
<td>Female</td>
<td>25.7</td>
<td>73.9</td>
</tr>
</tbody>
</table>

* The estimated incidence (point estimate) and [95% CI] of recent dengue infection, defined by the presence of either dengue IgM ≥ 0.2 OD or dengue IgG > 1:40.960.
† The estimated prevalence (point estimate) and [95% CI] of any past dengue infection (either recent or remote), defined by the presence of either dengue IgM ≥ 0.2 OD or dengue IgG titer ≥ 1:40.
§ Missing data from one Matamoros participant and three Brownsville participants.
†† Missing data from two Matamoros participants and three Brownsville participants.
We found that source reduction awareness was associated with dengue incidence in Matamoros. We had hypothesized that knowledge of source reduction as an important component in the control of dengue would be associated with lower dengue infection risk. Our finding of a positive association between prevention knowledge and dengue incidence in Matamoros was unexpected. We suggested the possibility of prevention messages being communicated, but not in a timely enough manner to prevent dengue infections. Also, knowledge of source reduction as important to control dengue does not necessarily mean preventive actions were taken. Our cross-sectional study design makes these results difficult to interpret: we do not know if aware-
ness of source reduction to prevent dengue preceded infection or *vice versa*.

Lack of air conditioning and not using insect repellent were both found to be associated with dengue infection in Matamoros. This protective effect of air conditioning is consistent with a 1999 study in the Laredo/Nuevo Laredo border area.\(^{17}\) We found that insect repellents were used “often or always” by 13% of Matamoros participants and had a protective effect against dengue infection. These data suggest an unexpected prevention opportunity, because earlier focus group data from border regions had suggested that repellent use would be very limited in Mexico (E. Zielinski-Gutierrez, unpublished data).

Discarded waste tires made up the single largest category of infested containers found in either city. In the subtropical climate of the region, the water holding capacity of tires, their insulating qualities that protect against weather extremes, and their dark color make tires an ideal oviposition habitat for *Aedes* mosquitoes.

The only factor found to be associated with recent dengue infection in Brownsville was smaller lot size. This finding could reflect denser concentration of people or could be related to socioeconomic factors.\(^ {18,26}\) Past dengue infection among Brownsville residents was associated with birth outside the United States, as expected given the high level of dengue transmission in Mexico.

**Limitations.** Short winter days limited available daylight hours in which to do surveying. Low temperatures may have hampered our ability to fully detect all mosquito larvae and pupae on premises. The mosquito populations detected during December may not have reflected those during the peak dengue transmission period. Small sample size limited our ability to detect statistically significant associations. Last, there may be recall bias in that data were collected retrospectively.

**Conclusions.** Dengue and, more recently, DHF are growing public health problems in the Texas–Mexico border area. The entomologic, serologic, and virologic conditions in South Texas could support the continued development of locally (US) acquired DHF: Abundant *Aedes* species mosquitoes were detected in December on both sides of the subtropical Texas–Mexico border. Because nearly 40% of Brownsville residents have been infected with DENV, a substantial proportion of the population is likely to be at increased risk for DHF should they acquire a second DENV infection, especially one with a virulent strain.\(^ {27}\)

We recommend strengthening dengue surveillance in the region to include more virologic testing. Actively monitoring for circulating DENV serotypes may provide early warning of outbreaks. Clinicians practicing in South Texas and the general public should be aware of the possibility of DHF and dengue fever in the region. Clinicians should be trained in recognizing and managing DHF. Last, prevention measures including repellent use and source reduction efforts involving waste tire disposal and proper storage of buckets should be encouraged by public health officials along both sides of the border.

Received October 16, 2007. Accepted for publication December 18, 2007.

Acknowledgments: The authors thank Carlos A. Carrillo, Oscar Velasquez-Monroy, CENAVECE, Secretaria de Salud de Tamaulipas, Jurisdicción Sanitaria No. III, Matamoros, Cameron County Department of Health and Human Services, City of Brownsville Health Department, Texas Department of State Health Services, Jim Schuermann, Chester Moore, Roberto Barrera, Joshua Smith, Carmen Perez, Elizabeth Hunsperger, and Nadonina Jones.

Authors’ addresses: Mary M. Ramos, Department of Pediatrics, University of New Mexico, 300 San Mateo NE, Suite 902, Albuquerque, NM 87109, Tel: 505-222-8684, Fax: 505-222-8675, E-mail: mramos@salud.unm.edu. Hamish Mohammed and Jorge L. Muñoz, Dengue Branch, Centers for Disease Control and Prevention, 3324 Calle Cañada, San Juan, Puerto Rico 00920-3860, Tel: (787) 706-2399, Fax: (787) 706-2496, E-mails: HMohammed@cdc.gov and ckq2@cdc.gov. Emily Zielinski-Gutierrez, Division of Vector Borne Infectious Diseases, Centers for Disease Control and Prevention, 3150 Rampart Road, Foothills Campus, Fort Collins, CO 80521, Tel: 970-221-6477, Fax: 970-226-3502, E-mail: ebzfb@cdc.gov. Mary H. Hayden, National Center for Atmospheric Research, PO Box 3000, Boulder, CO 80309, Tel: 303-497-8116, Fax: 303-497-8125, E-mail: mhayden@ucar.edu. Jose Luis Robles Lopez, Francisco Sarabia 153 Col. Mexico Agrario C.P. 87440, H. Matamoros Tamaulipas Mexico, Tel: (868) 8192565 and (868) 8102080, Fax: (868) 8174920, E-mails: jrrobles@salud.gob.mx and drjrobles@hotmail.com. Marta Fournier and Brian Smith, TX DSHS, Health Service Region 11, 601 W. Sesame, Harlingen, TX 78550. Tel: (956) 444-3227, (956) 444-3202, Fax: (956) 444-3299, E-mails: Marta.Fournier@dshs.state.tx.us and Brian.Smith@dshs.state.tx.us. Alfredo Rodríguez Trujillo, Palacio Federal 3r. Piso, Servicios de Salud de Tamaulipas, Cd. Victoria, Tamaulipas, Tel: (011-52-834) 315-68-83, Fax: (011-52-834) 315-68-83, E-mail: alfredor2@salud.gob.mx. Roy Burton, TX DSHS, PQA Environmental Health, 8407 Wall St., Austin, TX 78754, Tel: (512) 834-6773, x 2302, Fax: (512) 834-6706, E-mail: Roy.Burton@dshs.state.tx.us. Joan M. Brunkard, Epidemic Intelligence Service Program, Centers for Disease Control and Prevention, 3101 West Napoleon Ave., Metairie, LA 70001, Tel: 504-219-4732, Cell: 504-875-8584, E-mail: jbrunkard@cdc.gov. Luis Anaíz-Lopez, Director de Servicios y Apoyo Técnico, CENAVECE/InDRE, Carpio No. 470, Col. Sto Tomás, Deleg. Miguel Hidalgo, Mex. D.F., 11340, Tel: (011-52-55) 5396-4986, 7350 7550 X.204 o 303, Fax: (011-52-55) 341 32 64, E-mail: anayaluis@hotmail.com. Allison Abell Banicki, Office of Border Health, Texas Dept. of State Health Services, 1100 W. 49th St., Austin, TX 78756, Tel: 512-438-7111 ext 6705, E-mail: alissan.abell@dshs.state.tx.us. Pablo Kuri Morales, Francisco de P. Miranda No. 177, 4° Piso, Colonia Lomas de Plateros, 01480 México, Distrito Federal (DF), Tel: (011-52-55) 5337-1664 al 66, Fax: (011-52-55) 5337 1667, E-mail: pkuiri@dgepi.salud.gob.mx. Stephen H. Waterman, San Diego Quarantine and Border Health Services, Division of Global Migration and Quarantine, Centers for Disease Control and Prevention, 3851 Rosencrans Street, PO Box 85524, San Diego, CA 92138, Tel: (619) 692 3659, E-mail: shw2@cdc.gov.

REFERENCES


