Current Status of Mosquito-Borne Viruses in North America

John D. Edman
Mosquito-Borne Virus Threats to Humans In North America

- **Togaviridae (genus Alphavirus)**
  - Eastern equine encephalitis virus **
  - Western equine encephalitis virus **
  - Venezuelan equine encephalitis virus **

- **Bunyaviridae**
  - California encephalitis viruses (La Crosse, etc.)

- **Flaviviridae**
  - West Nile virus **
  - St Louis encephalitis virus
  - Dengue viruses

**Virus that also effect horses**
Some Generalizations

All mosquito-borne human arboviral diseases are zoonotic and occur naturally in non-human vertebrate hosts, often without visible symptoms. Humans and horses are generally dead-end hosts.

Human infections vary from inapparent to flu-like symptoms to severe neurological, paralytic or hemorrhagic symptoms (some residual) & death. Infection results in life-long immunity.

Symptoms in humans & horses occur ~3-10 days (usually 6-7 d) after the infected mosquito bite, etc. Old or young people are most affected. Horse mortality (>50%) is higher than in humans (<1-~25%)

None of the arboviruses can be cycled or maintained in humans except for the dengue viruses. VEE can briefly cycle in horses but is not maintained in horses.

There are currently no licensed vaccines to protect humans against any of these viral disease. Horses vaccines exist for EEE, VEE, WEE, WN.

Good surveillance together with appropriate protective and vector control measures is currently the only public health strategy for avoiding severe outbreaks of arboviral diseases in humans.
Components in the Transmission and Maintenance of Arboviral Encephalitis
Surveillance Indicators Along Virus Amplification or Epidemic Curve

- Human cases
- Equine, etc. cases
- Avian infection
- Mosquito infection
- Mosquito abundance
- Climate

TIME [months]
AMPLIFICATION
Mosquito Surveillance

CO$_2$-Baited CDC Miniature Light Trap

CDC Gravid Trap
Captive Bird Surveillance

Serum samples tested for IgG antibody

Lancet Prick of comb

Whole sera needed for PRNT or IgM testing

Jugular puncture
# Reservoir Hosts and Vectors

<table>
<thead>
<tr>
<th>DISEASE</th>
<th>SYLVAN HOST</th>
<th>SYLVAN VECTOR</th>
<th>HORSE*/HUMAN VECTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEE</td>
<td>Birds</td>
<td>Cs. melanura</td>
<td>Aedes, Coquillettidia</td>
</tr>
<tr>
<td>WEE</td>
<td>Birds</td>
<td>Cx. tarsalis</td>
<td>Cx. tarsalis*</td>
</tr>
<tr>
<td>VEE</td>
<td>Rodents</td>
<td>Cx. (Melan.)</td>
<td>Aedes, Psorophora</td>
</tr>
<tr>
<td>CE/LAC</td>
<td>Chipmunk</td>
<td>Ae. triseriatus</td>
<td>Ae. triseriatus*</td>
</tr>
<tr>
<td></td>
<td>Tree squirrels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLE</td>
<td>Birds</td>
<td>Culex spp.</td>
<td>Culex spp.*</td>
</tr>
<tr>
<td>WNV</td>
<td>Birds</td>
<td>Culex spp.</td>
<td>Culex spp.*</td>
</tr>
<tr>
<td>DEN</td>
<td>Wild Primates</td>
<td>Forest</td>
<td>Ae. aegypti</td>
</tr>
</tbody>
</table>

* No bridge vector required
Togaviridae

- Eastern equine encephalitis
- Western equine encephalitis
- Venezuelan equine encephalitis
Culiseta melanura

EEE Epidemiology
Distribution of Human Cases of EEE

Human Eastern Equine Encephalitis Cases by State, 1964-2004

CDC
Eastern Equine Encephalitis

Total Cases in U.S. 1964-2006

Reported Human Cases
Average = 5/year; Range = 0-21
## Confirmed & Probable Eastern Equine Encephalitis - All States

**Human Cases - 1986-2005**

<table>
<thead>
<tr>
<th></th>
<th>1986-90</th>
<th>1991-95</th>
<th>1996-00</th>
<th>2001-05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>21</td>
<td>23</td>
<td>31</td>
<td>60</td>
</tr>
</tbody>
</table>
Severe but rare neurological disease of humans (usually children), horses & non-native birds in Eastern U.S. & Great Lakes region.

Incidence increasing due to human encroachment?

Enzootic maintenance cycle in wetland forest birds.

Overwintering of virus unresolved (birds, mosquitoes, other?).

Different vectors in avian & human/horse transmission (Cs melanura verses Aedes spp, Cq perterbans, Cx nigripalpus).

Difficult to do mosquito source reduction & chemical treatment in valued wetlands, so surveillance is critical.

Zoning to avoid development near wetlands.
Togaviridae

- Eastern equine encephalitis
- Western equine encephalitis
- Venezuelan equine encephalitis
Western Equine Encephalitis
Human cases: 1964-2005

Human Cases Reported from 21 States
Western Equine Encephalitis
Total Cases in U.S. 1964-2006

Reported Human Cases
Average = 15/year; Range = 0-172
WEE Summary

- Serious but rare neurological disease of humans and horses in the central and northern Great Plains and irrigated valleys in the West, including Southern California.
- Less human mortality than EEE; no cases recently.
- Natural cycle in wild birds; commonly the more domesticated species.
- *Cx tarsalis* is the main vector to both avians and horses/humans but also *Aedes* spp in some areas.
- Overwintering mechanism unknown (TOT?).
Togaviridae

- Eastern equine encephalitis
- Western equine encephalitis
- Venezuelan equine encephalitis
Serious equine & mild human neurological disease in South and Central America that occasionally invades Mexico and U.S. border areas (last time was 1971).

Both enzootic and epizootic/epidemic strains exist but enzootic strains do not cause disease.

Maintained by forest rodents and *Culex* (*Melanoconion*) mosquitoes.

Epidemic transmission by flood-water *Aedes* and *Psorophora* spp. Sick horses have extremely high viremias and can infect mosquitoes.
Bunyaviridae

California Group viruses
  • LaCrosse encephalitis virus*
  • California encephalitis virus
  • Jamestown Canyon virus
  • Cache Valley virus, etc.

* Most important
CE Encephalitis
Human cases: 1964-2005

Human Cases Reported from 30 States
La Crosse Encephalitis
California Encephalitis

Total Cases in U.S. 1964-2006

Reported Human Cases
Average = 80/year; Range = 29-167
Restricted to Eastern half of U.S.; major foci in Upper Midwest & Central Appalachian regions.
Mainly affects children under 16 years old.
Naturally cycle in chipmunks & tree squirrels in deciduous hardwood forests.
Vectored by day-biting treehole mosquito, *Ae triseriatus*.
Transovarial & venereal transmission in vector (virus over-winters in mosquito eggs).
Human cases often associated with discarded tires, etc. in shaded areas near homes.
Tire clean up and filling of tree holes.
Flaviviridae

- West Nile fever virus
- St Louis encephalitis virus
- Dengue fever viruses (1, 2, 3, 4)
Outbreak
Encephalitis, Rare in City, Kills at Least 1, Infects Dozens in Queens / Page A5

Summer of 1999
West Nile's Westward Spread

1999

Incidence per million
- ≤0.00
- 0.00-9.99
- ≥100

2000

Incidence per million
- ≤0.00
- 0.00-9.99
- ≥100

2001

Incidence per million
- ≤0.00
- 0.00-9.99
- ≥100

2002

Incidence per million
- ≤0.00
- 0.00-9.99
- ≥100

Any WNV Activity
2007 Human Cases as of October 7

2803 human cases reported to date
337 horse cases despite wide vaccine use
70 human deaths
West Nile Virus
Total Cases in U.S. 1999-2006

Reported Human Cases Reported
Average = 2969/yr; range = 21-9862
## WN Virus Isolations - 2002

<table>
<thead>
<tr>
<th>Genus</th>
<th>Positive Pools</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culex</td>
<td>6,217</td>
<td>94.1</td>
</tr>
<tr>
<td>Aedes / Ochlerotatus</td>
<td>252</td>
<td>3.8</td>
</tr>
<tr>
<td>Anopheles</td>
<td>67</td>
<td>1.0</td>
</tr>
<tr>
<td>Psorophora</td>
<td>18</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Coquillettidia</td>
<td>12</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Culiseta</td>
<td>9</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Orthopodomyia</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Uranotaenia</td>
<td>4</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Unknown</td>
<td>17</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>
WN brought together some unusual partners...
No. of Reported, Submitted, and WNV-Infected Crows, 2000

- Reported
- Submitted
- Positive

= Onset human illness
Birds as Dispersal Vehicles

Virus move south with fall migration and north & west with spring migration?
WNV Summary

- Old World virus introduced into NYC in 1999, it is now the most important arbovirus in the U. S.
- In just 5 yrs, it spread to every State, Mex. & Can.
- WNV mainly affects the elderly, neuro & paralytic.
- Cycles in and kills many new world birds; especially crows & jays.
- WNV also isolated from many mammals and reptiles.
- Vectored by several species of *Culex* often associated with semi-permanent irrigated or polluted water.
- Also isolated from a large number of other species.
- Can overwinter in adult mosquitoes or migrating birds.
Flaviviridae

- West Nile fever virus
- St Louis encephalitis virus
- Dengue fever viruses (1, 2, 3, 4)
St. Louis Encephalitis
Human cases: 1964-2005

Human Cases Reported from 43 States
St. Louis Encephalitis
Total Cases in U.S. 1964-2006

Reported Human Cases
Average = 111/yr; Range = 2-1967
SLE Summary

- Close relative of WN virus but does not cause disease in equines.
- Elderly at highest risk of severe neurological disease.
- Most widespread and abundant arbovirus in the U.S. prior to the arrival of WNV. Few cases recently (AZ).
- Naturally cycles in wild birds, especially peridomestic species.
- Similar *Culex* vectors to WNV (not as high titered or in as many other mosquito species).
- Over-wintering mechanism unknown.
Flaviviridae

- West Nile fever virus
- St Louis encephalitis virus
- Dengue fever viruses (1, 2, 3, 4)
Dengue Fever & DHF
Worldwide Distribution

Dengue and Aedes aegypti

Areas infested with Aedes aegypti
Areas with Aedes aegypti and recent dengue epidemic activity
Reported New World Dengue Cases - Last 10 Yrs

Total = 5,304,042 cases
DHF  113,072 cases
Deaths  1,410 cases
American Countries with laboratory confirmed dengue hemorrhagic fever, prior to 1981 and from 1981 to 2003

Prior to 1981

1981 - 2003

Source: WHO/PAHO/CDC, Aug. 2004
Changing Distribution of Ae aegypti
Current U.S. Distribution of Ae albopictus
Recent Dengue in the U.S. (Texas)

- Dengue epidemics occurred in the US in the 1800s and up until 1945.

- Recent indigenous transmission
  - 1980: 23 cases, first locally acquired since 1945
  - 1986: 9 cases
  - 1995: 7 cases
  - 1997: 3 cases
  - 1998: 1 case
  - 1999: 18 cases
Hawaiian Islands Outbreak 2001–2002

Transmitted by *Aedes albopictus*
122 Lab Positive Infections

Source: Emerg Infect Dis © 2004 Centers for Disease Control and Prevention (CDC)
Most important arbovirus worldwide with hundreds of thousands of cases and millions at risk annually in tropical regions. Case numbers are increasing.

Four different dengue strains exist with only short term cross-strain immunity follow infection.

DHF and DSS are often related to 2nd infections with a different strain. Mostly in children.

Sylvan cycles in wild primates have been recently documented in Asia and Africa for 3 of 4 DEN strains. Sylvan vectors are canopy *Aedes* spp.

*Ae aegypti* is the main vector in all urban and many rural areas. *Ae albopictus* is a vector in rural areas.

Several vaccines have been under development for many years. Difficult strain-related problems.