Emerging vector-borne diseases in the United States: What’s next and are we prepared?

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Emerging Infectious Disease

as Defined by Wikipedia

- Incidence increased in last 35 years or could increase in future*
- Caused by
  - Newly identified strains that may have involved from a known infection or spread to a new population or area undergoing ecologic transformation or
  - Remerging infections

* IOM report 1992: new, reemerging, or drug-resistant infections whose incidence in humans has increased within the past two decades or whose incidence threatens to increase in the near future.
Simplified Patterns of Vector-Borne Disease Transmission

Scenario one: People are incidental hosts

Scenario two: People are primary hosts
## Vector-Borne Disease Emergence in the United States

<table>
<thead>
<tr>
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Vector-Borne Disease Transmission: 
*Humans as Incidental Hosts*

- **Common features**
  - Incredibly complex transmission cycle
  - High turnover in many animal reservoirs – herd immunity temporary
  - Human immunity not important to transmission cycle

- **Mosquito-borne**
  - Amplifies quickly
  - Influenced by factors not easily measured or predicted far in advance
  - Stochastic process subject to substantial random variability
  - Unpredictable outbreaks garner public attention

- **Tick-borne**
  - Amplifies slowly in comparison
  - More predictable
  - Long-term trends garner less public attention
### Vector-Borne Disease Emergence in the United States

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West Nile Virus

- Flavivirus
- Birds are vertebrate hosts; *Culex* mosquitoes vectors
- Introduced into New York City area in 1999
- No means of natural transport to Western Hemisphere
- Emergence during a heat wave
- Genetics suggests separate introductions in Europe and USA of lineage 1 WNV from Africa
- At least two sequential genetic mutation events of consequence
  - NY99 strain: NS3 T249P mutation increases viremia and mortality in birds
  - WN02 strain: E-V159A mutation changes viral transmission dynamics in birds and mosquitoes
- Continued co-evolution: Birds becoming less susceptible to illness and death, but viruses creating higher viremia
Estimated Number of West Nile Infections and Illnesses, 1999-2013

- 17,460 neuroinvasive disease cases reported
- For every reported neuroinvasive disease case,
  - 30 - 70 non-neuroinvasive disease cases
    - 524,000 - 1.2 million non-neuroinvasive disease cases
  - 150 - 300 infections
    - 2.6 - 5.2 million infections

- Economic cost of hospitalized patients through 2012: $778 million
Average annual incidence of WNV neuroinvasive disease – United States, 1999–2013
Average annual incidence of WNV severe neurological disease by county – United States, 1999–2013
Average annual number of WNV neuroinvasive disease cases by county – United States, 1999-2013
## Vector-Borne Disease Emergence in the United States

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Distribution of Key Tick-Borne Diseases, 2012

NOTE: In 2012, no cases of tickborne illness were reported from Hawaii. In 2012, Alaska reported ten travel-related cases of Lyme disease.

Diseases reported to CDC by state health departments. Each dot represents one case. The county where the disease was diagnosed is not necessarily the county where the disease was acquired.

- Lyme disease
- Rocky Mountain spotted fever
- Anaplasmosis
- Ehrlichiosis
Notifiable Tick-Borne Diseases in the U.S.

• *Ixodes scapularis* (Blacklegged tick)
  – Anaplasmosis
  – Lyme disease
  – Babesiosis
  – Powassan (deer tick virus) infection

• *Amblyomma americanum* (Lone star tick)
  – Ehrlichiosis

• Multiple tick species
  – Rocky Mountain spotted fever
Ixodes scapularis: A Growing Concern

• Increased frequency and distribution
  – Reforestation
  – Habitat fragmentation
  – Increased deer populations
  – Climate change
• Increased exposure to tick habitat
  – Suburbanization

Deer populations in CT
Reported Tick-Borne Diseases in the United States, 2004-2013

*Includes HGA, HME, and other or unspecified ehrlichiosis
†Babesiosis became nationally notifiable in 2010
Reported Cases of Lyme Disease by Year, United States, 1996-2013

*National Surveillance case definition revised in 2008 to include probable cases; details at http://www.cdc.gov/ncphi/disss/nndss/casedef/lyme_disease_2008.htm
Lyme Disease U.S. Case Distribution – 17-Year Trend

Lyme Disease Incidence Exceeds 300,000 Cases Annually

Three independent approaches:

• The number of people who tested positive, based on data from a survey of clinical laboratories

• The number of people diagnosed, based on medical claims information (ICD9 codes)

• Survey data to estimate the number of people who report that they’ve been diagnosed with Lyme disease in the previous year
Recently Recognized Tick-Borne Pathogens in the United States

- Heartland virus (*Amblyomma americanum*)
- *Borrelia miyamotoi* and other novel borrelia (*Ixodes scapularis*)
- 364D rickettsiosis (*Dermacentor occidentalis*)
- *Rickettsia parkeri* (*Amblyomomma maculatum*)
- *Ehrlichia muris*-like organism
Heartland Virus

- Two Missouri patients suspected of having ehrlichiosis positive for a novel phlebovirus related to SFTS virus
- Common features at presentation: Fever, fatigue, headache, nausea, myalgia, arthralgia, thrombocytopenia, and leukopenia.
- Seven additional cases have now been reported, in Missouri, Oklahoma, Tennessee*
  - Five hospitalized, two died
- *Amblyomma americanum* suspected tick vector**
- Serological evidence indicates widespread exposure to wildlife

* MMWR 2014;63:270-1, Clin Infect Dis (on line)
Vector-Borne Disease Emergence in the United States

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- Arboviruses
- Bacteria
- Parasites
Dengue

- Caused by four flaviviruses
- No known important animal reservoir
- Causes fever, rash, severe pain ("break bone fever"), shock, hemorrhage
- Subsequent infections increase likelihood of severe disease
- 400 million infections per year globally
- Transmitted by *Aedes aegypti* mosquitoes
  - Have resurged in the Americas since control efforts stopped in 1970s
- *Aedes albopictus* can also sustain transmission
  - Introduced to the Americas in 1985
Dengue Incidence is Rapidly Increasing in the Americas

Source: Pan American Health Organization (PAHO)
Can Dengue Reemerge in Temperate Climates?

*Dengue in the Continental USA*

- Dengue epidemics until first half of the 1900s
- 807 returning travelers with dengue reported in 2013
- 8 outbreaks in Texas since 1980
- 2 outbreaks in Florida since 2009

*Maps showing the distribution of Aedes aegypti and Aedes albopictus in the USA.*
Environmental Parameters Limit Dengue Transmission in the Contiguous States

Example: *Dengue Outbreak on the US-Mexico Border*

- 8 times more infections in Matamoros
  - 4% infected in Brownsville
  - 32% in Matamoros
- Substantial *Aedes aegypti* infestations in both locations
- Different environmental conditions
  - 85% homes air conditioned in Brownsville; 29% in Matamoros
  - Lot size 3 times greater in Brownsville
- No air conditioning increased dengue risk 7 fold in Matamoros
- Smaller lot size increased dengue risk 15 fold in Brownsville
Chikungunya Virus

Makonde language: “to dry up or become contorted”

• Alphavirus
• Like dengue
  – Man-mosquito-man transmission cycle
  – *Aedes aegypti* is the traditional urban vector
  – Also spread by *Aedes albopictus*
• Most infected persons symptomatic (76%-97%)
  – Fever (76-100%) and joint pain (71-100%) most common symptoms
• Outbreak in Americas began in late 2013 in St. Martin
Chikungunya in the Americas*

706,093 reported cases
113 reported deaths

* Reported to PAHO as of Sept 12
Chikungunya in the Western Hemisphere

Countries and territories in the Americas where autochthonous chikungunya cases have been reported (as of September 9, 2014).
Chikungunya in the Contiguous United States*

Historically, from 2006–2013:
• An average 28 people/year with positive tests for recent CHIKV infection
• (Range 5–65 per year)

Current Outbreak
• 43 states reporting cases
• 934 travel-associated cases
  • 202 (22%) NY
  • 184 (20%) FL
• 8 locally-acquired cases (FL)

* As of Sept 9, 2014; includes HI and AK

http://www.cdc.gov/chikungunya/geo/index.html
What’s Next?

- West Nile virus will continue to cause focal and regional outbreaks
- Dengue and chikungunya virus will remain significant problems in US territories (chikungunya at least for the short-run)
- Tick-borne diseases will continue to increase in incidence and distribution
- Discovery of novel tick-borne pathogens, some of public health significance
- Importation and emergence of pathogens not currently endemic to the US
Are we prepared?

- ArboNET surveillance system
  - National in scope
  - Human, animal, vector data
  - Flexible
  - Capacity eroding
- Tick-borne disease surveillance
  - Surveillance present, but incomplete and overwhelmed
- Advanced molecular detection: Greatly improved capacity for detection of imported and novel agents
- Communication capacity greatly improved
Are we prepared?

- Increasing knowledge of ecologic parameters of pathogen transmission
- Developing vector-borne disease modeling capacity
- Surveillance can indicate impending WNV outbreaks (at least for the short-run) and aggressive measures can stop them, but
  - Many localities aren’t prepared to respond quickly
    - Lack of adequate surveillance
    - Lack adequate mosquito control
    - Political controversy
    - Pesticide resistance
Are we prepared?

- Have good treatment regimens for bacterial vector-borne diseases, but
  - Delayed recognition and improper treatment increases morbidity and mortality
  - Lack sensitive diagnostics for early diagnosis of rickettsial diseases and Lyme disease
- Blood donor screening has almost eliminated the risk of WNV and Chagas disease
  - But at considerable expense
  - Doesn’t cover other pathogens, such as dengue, babesia, chikungunya, ehrlichiosis, anaplasmosis
- Promising late-stage development of dengue vaccines
Are we prepared?

- Safe and likely effective WNV vaccine constructs exist
  - But no regulatory pathway to bring them to market and may not be sufficiently profitable
- New and effective public health pesticides are in development
  - But unclear if any will be marketed
- New non-pesticide vector control tools in development
  - Unclear which will be operationalized
Are we prepared?

- No effective, scalable vector control method for *Ixodes scapularis* or *Aedes aegypti*
- No Lyme disease vaccine
- No arboviral therapeutics
  - No regulatory pathway to market
- Entomologic and ecologic research and training capacity disappearing rapidly
The findings and conclusions in this presentation are those of the author and do not necessarily represent the views of the Centers for Disease Control and Prevention.