Mosquito Biology, Disease Risk, and Personal Protection

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Major Mosquito-borne Diseases
Parasitic infections:
- Malaria (Global tropics)
- Lymphatic Filariasis (Global tropics)

Viral infections:
- Dengue (Global tropics)
- Chikungunya (Global tropics)
- Yellow Fever (South America and West Africa)
- Zika (Global tropics)
- Japanese Encephalitis (South and East Asia)
- West Nile Virus Encephalitis (Global distribution)
- Rift valley fever (Africa)
- Venezuelan Equine Encephalitis (South and Central America)
- Ross River virus fever (Australia)

Mosquito Basics
- Four stages of development:
  - Egg → larvae → pupae → adult
- Exploit newly created water bodies for development
- "Boom and bust" lifecycle
- 1-2 weeks to complete development
- Only adult female mosquitoes feed on blood
- Both sexes feed on plant sugars- nectar, plant juices

Mosquito host location
- Search for hosts at certain times of the day
  - Activity varies by species
  - Diurnal, crepuscular, nocturnal feeders
- Respond to various stimuli to locate their hosts
- Host odor: carbon dioxide, skin and sweat volatiles (<50 meters)
  - Move upwind to orient to distant odor sources
- Visual cues: color, contrast, movement (<10 m)
- Thermal cues: radiant body heat (<1 m)

Mosquito blood feeding
- After landing mosquitoes quickly obtain a blood meal
- Have piercing mouthparts (proboscis)
- The outer sheath (labrum) bends back while the styllet penetrates into the skin
- Mosquitoes repeatedly stab the skin with their mouthparts
- They inject saliva which contains anti-hemostatic and anesthetic compounds
- After finding a vessel, mosquitoes ingest up to four times their weight in blood
Mosquito Vector - *Aedes aegypti*

- Primary urban vector of Dengue, Yellow Fever, Chikungunya, and Zika viruses – “Yellow Fever Mosquito”
- Worldwide distribution – limited to tropical and subtropical climates
- Generally found between 10°C January isotherm in northern and western hemispheres
- Ubiquitous in populated area of the tropics and subtropics
- Closely associated with human habitation
- Ranging from small rural villages to megacities

Aedes aegypti - Biology

- Oviposits eggs in natural and artificial containers around human dwellings as preferred larval development sites
- Adult females lay eggs on the sides of water holding containers ~ 100 to 200 per gonotrophic cycle
- Eggs can survive desiccation up to 6 months
- Development is temperature dependent
- Larvae ~ 4 to 9 days; Pupae ~ 3 to 7 days

Aedes aegypti - Adult Behavior

- Females commonly rest inside houses in quiet dark places (closets)
- Feed indoors and out
- Feed predominately on human blood
- Bite during the day, “stealth biters”
- Often take several partial blood meals during a single gonotrophic cycle – increases vectorial capacity
- Adults have a limited flight range ~ 100 meters
- Epidemics can occur even when mosquito densities are low

Malaria Vectors - *Anopheles*

- About 40 species serve as malaria vectors
- Typically found in rural and peri-urban areas
- Eggs do not survive desiccation
- More adapted to permanent water bodies than *Aedes*
- Habitats vary by species such as:
  - Irrigated fields
  - Ground pools with emergent vegetation
  - Water impoundments
  - Natural swamps
- Most species are crepuscular or nocturnal

Distribution of Malaria Vectors

**Anopheles gambiae**
- Important malaria vector in Africa
  - Where 90% of malaria deaths occur
- Associated with rural villages
- Exploits sunlit pools- burrow pits, drainage ditches, ground depressions close to homes
- Reaches maximum density after seasonal rain
- Typically found indoors
- Feeds mainly on people at night
- Insecticide treated bed-nets effective against this species

**Culex species**
- Vectors of viral encephalitis and lymphatic filariasis
- Found in urban, peri-urban, and rural areas depending on species
- Breed in highly contaminated water including:
  - Drainage and irrigation ditches
  - Cesspools
  - Storm drains
  - Sewage waste lagoons
- Blood feeding activity- crepuscular or nocturnal
- *Culex quinquefasciatus*
  - Important vector of filariasis and West Nile virus
  - Global distribution in tropical and warm-temperate climates

**Prevention Strategies for Travelers**
- Limit exposure to mosquitoes when most active
  - *Aedes aegypti*- daytime
  - *Anopheles* and *Culex*- dusk to dawn
- Use an EPA approved insect repellent and apply according to directions
  - Cover-up: shoes, socks, long pants, and long-sleeved shirts. Clothing material should be light or neutral-colored and tightly woven.
  - Consider wearing insecticide-treated (permethrin) clothing
  - Sleep in well-screened or air-conditioned rooms
  - Sleep under an insecticide-treated bednet

**Insect Repellents- DEET**
- Pros: effective, low toxicity, most-studied insect repellent
- Cons: Oily, smelly, can damage plastic, not always accepted by patients
- Sold in concentrations 5 to 98%
  - 15-30% recommended
- Lasts 2-8 hours depending on concentration
- Controlled release formulations last 8-12 hours
- Approved for use in children >2 years of age
  - Do not apply to child’s hands or face

**Alternatives to DEET**

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Concentration</th>
<th>Protection Time</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picaridin</td>
<td>5-30% (20% recommended)</td>
<td>2-8 hours</td>
<td>Synthetic version of compound from black pepper plant, available in US since 2005</td>
</tr>
<tr>
<td>Oil of Lemon</td>
<td>10-40% (≥30% recommended)</td>
<td>2-8 hours</td>
<td>Natural product. Approved for use in children &gt;3 years.</td>
</tr>
<tr>
<td>IR3535</td>
<td>7.35% (≥20% recommended)</td>
<td>2-8 hours</td>
<td>Synthetic compound available in US since 1999 (since 1970’s in Europe). Not very effective against Anopheles mosquitoes</td>
</tr>
<tr>
<td>2-undecanone</td>
<td>7.75%</td>
<td>4 hours</td>
<td>Registered in US in 2007. Active ingredients derived from wild tomato plants</td>
</tr>
<tr>
<td>Botanical extracts</td>
<td>Varies</td>
<td>Generally &lt;1 hour</td>
<td>Natural oils (soybean, lemongrass, citronella, cedar, peppermint, lavender, geranium). Not registered by the EPA, no assurance that products work.</td>
</tr>
</tbody>
</table>

**Clothing Only Repellent Permethrin**

Fabric treatment options for consumers

Factory Impregnated Clothing
Efficacy of Mosquito Repellents for Malaria Prevention


- Tropical repellents applied to the skin
  - 5 of 6 studies found no evidence of a protective effect against clinical malaria
  - Poor compliance and amount applied were major limitations to this intervention
- Spatial repellents- burning insect coils
  - 2 studies showed no evidence of a protective effect
  - Adherence to daily compliance remains a major limitation
- Permethrin- treated clothing
  - 2 studies showed a ~50% reduction in clinical malaria
  - Adherence to daily compliance remains a major limitation
- Need for better designed studies to evaluate efficacy for these prevention measures

Conclusions

- Relatively few mosquito species serve as disease vectors
- The most effective vectors exploit disturbed environments caused by human activity and readily feed on people
- In the absence of vaccines or chemoprophylaxis, personal protection measures against mosquito bites are the primary means for protecting travelers
- Protective clothing, topical repellents, insecticide-treated clothing and bednets should be recommended to travelers to endemic areas
- These are imperfect tools but may be more effective when used in combination
- Poor compliance may undermine the efficacy of these measures

Bednets

- Insecticide-treated bednets a foundation for malaria prevention in many regions
  - Particularly effective in sub-Saharan Africa where Anopheles vectors bite predominately indoors
  - Reduce malaria mortality by ~20% and clinical episodes by ~50%
  - Rise of pyrethroid resistance may undermine the effectiveness of nets
  - A good option in the absence of well-screened or air-conditioned housing

Not recommended

- Botanical repellents not approved by the EPA
- Repellents mixed with sunscreen
  - difficult to regulate dose
- Citronella Candles and mosquito coils
  - May not be effective
  - Emit fumes that could trigger respiratory problems
- Bug zappers
- Sonic repellents
- Treated wristbands
- Aerosol insecticide sprays

Thank you!