Malaria Epidemiology, social and ecological perspective

Goals for today

- Understand different types of epidemiological measurements for malaria and how they are used
- Consider the complexity of factors (determinants) that influence malaria transmission
- Understand the economic impact of malaria at the household and national level
- Understand the cost-benefit approaches used for malaria public health decision making

Determinants of malaria transmission

- **Host determinants:** age, immunity, genetics, behavior
- **Parasite determinants:** species, virulence, genotype, drug resistance, reproductive rate
- **Vector determinants:** feeding preference, feeding frequency, longevity, abundance
- **Environmental determinants:** temperature (18°C), rainfall/humidity, landscape ecology and altitude, climate change?
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Classification of major malaria epidemic types. From: Worrall et al. The Burden of Malaria Epidemics and Cost-Effectiveness of Interventions in Epidemic Situations in Africa

Cycles of disease

Recurrent epidemic malaria in an epidemic-prone site in Ethiopia. Shown are Plasmodium falciparum cases diagnosed by examination of blood smears at the Hirna Sector Malaria Laboratory, Harer Region, West Harerge, Ethiopia between July 1991 and June 2001 (Ministry of Health, Ethiopia, unpublished data).


Malaria surveillance

Incidence rate = the number of new cases occurring within a set time interval (hard to measure, why?)

Prevalence rate = the number of cases of disease present in a population at a given time (approx. incidence x duration)

Incidence rate (per person-years):

\[
IR = \frac{\# \text{new cases per unit time}}{\# \text{persons at risk during time}}
\]

Ex: 9,230 new cases of malaria observed over 1 yrs, with 105,000 people in study that time

IR = 9,230 new cases
105,000 persons at risk
= 0.0879 new malaria cases per person/year
(or 87.9 new cases per 1000 person/years)

Global malaria incidence
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**Age adjustment for incidence is critical for understanding risk:**


**Entomological inoculation rate**

\[ EIR = ma \]

- \( EIR \) = # of infective bites per unit time
- \( m \) = vector density in relation to host
- \( a \) = # of human blood meals per vector per day
  - \( m \times a \) can be estimated using human biting collections
- \( s \) = sporozoite rate (proportion of mosquitoes with malaria parasites in their salivary glands)

**Epidemiological inoculation rate**

- 15 Anopheles collected per person per night (=m), 78% are human-fed (=a) and 10% are infected with sporozoites (=s: sporozoite rate)
- \( EIR = \# \) mosquitoes x proportion human fed x proportion with sporozoites
  - \( 15 \times 0.78 \times 0.1 = 1.17 \)
  - Each individual receives 1.17 infective bites per night

**Basic reproductive rate = \( R_0 \)**

- The average number of secondary cases that a single case may cause in a completely non-immune population
- This determines transmission stability of an infection:
  - When \( R_0 < 1 \), the infection will die out
  - If \( R_0 > 1 \), there is a possibility of a major epidemic

**Herd immunity**

-当免疫对感染的保护作用时，免疫的多数人口（或群体）提供保护给非免疫个体

- Herd immunity lowers \( R_0 < 1 \)

**Disability-adjusted life year (DALY)**

- A measure of overall disease burden
- Combines mortality and morbidity in one common metric

- One DALY = one year of healthy life lost

April 10, 2008
The direct, indirect and consequential public health effects of Plasmodium falciparum malaria in Africa (Source: Snow & Gilles, 2002)

Treatment side effects
- Inappropriate drug management for uninfected

- Adverse effects on children's health due to negligence of antimalarials or mismanagement of treatment

Disease progression

- Clinical disease
- Severe clinical complications
- Death

Ways in which malaria imposes economic burden:

Household level:
- changes behavior in response to disease

Ways in which malaria imposes economic burden:

- "high fertility/high mortality" environment
  - impacts allocation of resources to children (education, food, medicine)
  - limits earning potential of women
  - increases productive time lost on children who die
  - reduces household savings

Table 21.1: Deaths and DALYs from Directly Attributable to Malaria in Malaria Regions, 2000

<table>
<thead>
<tr>
<th>Region</th>
<th>Population</th>
<th>Deaths</th>
<th>DALYs</th>
<th>Mortality rate</th>
<th>DALYs</th>
<th>DALYs</th>
<th>DALYs</th>
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<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>1,123,161</td>
<td>95,574</td>
<td>36,502</td>
<td>1.04</td>
<td>105.0</td>
<td>42.75</td>
<td>31.25</td>
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<tr>
<td>Asia</td>
<td>5,60,402</td>
<td>4,091</td>
<td>1,657</td>
<td>0.74</td>
<td>18.9</td>
<td>15.1</td>
<td>7.0</td>
</tr>
<tr>
<td>America</td>
<td>557,257</td>
<td>3,241</td>
<td>117.0</td>
<td>1.20</td>
<td>42.1</td>
<td>30.9</td>
<td>12.2</td>
</tr>
<tr>
<td>Europe</td>
<td>246,891</td>
<td>1,196</td>
<td>7.0</td>
<td>0.40</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>1,249,962</td>
<td>12,307</td>
<td>23.9</td>
<td>0.98</td>
<td>0.86</td>
<td>0.54</td>
<td>0.25</td>
</tr>
</tbody>
</table>


"As a general rule of thumb, where malaria prospers most, human societies have prospered least." – Sachs and Malaney

World Malaria Report

http://www.who.int/malaria/wmr2008/

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Ways in which malaria imposes economic burden:

National level - macroeconomic changes

- limits industry and foreign investment
- limits tourism

“While there is widespread agreement that incentives for drug discovery are essential to provide appropriate incentives for pharmaceutical firms to invest in research and development, one consequence is that drugs for diseases that affect poor countries may be unaffordable.”

Cost effectiveness analysis (CEA) of interventions:

- Informs decisions about how to allocate public sector health funds
- Cost effectiveness ratio (CER) can be calculated to compare interventions
- Expressed in terms of DALYs

Examples:

- Insecticide treatment of existing nets: $4-10 per DALY
- Providing nets and retreatment: $19-85 per DALY
- Treating pregnant women: $4-9 per DALY

Social marketing of bed nets:

- The use of commercial marketing techniques in promotion and distribution of health services, not for profit, but to achieve social goals
- Integrates response to consumer needs (example: net colors and shapes in Tanzania)
- Often limits sales to high risk groups (pregnant women and children < 5

What are some criticisms?

President’s malaria initiative in 2005–present
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WHO consultants estimate 2.2 billion/year would increase African GDP substantially.

How much is enough for malaria control?

Is a focus on control in Africa appropriate?

30% of global mortality due to malaria is in Southeast Asia and the highest global concentration of drug resistance.