Application of microsimulation modeling for malaria control decision-making

Erin M. Stuckey
SwarmFest
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OpenMalaria is able to aid in the decision-making process for trial design and intervention evaluation when applied to operationally-feasible contexts


Investigating operational strategies for antimalarial drug administration in Zambia’s Southern province: a simulation study. *In prep.* Erin M. Stuckey, John M. Miller, Megan Littrell, Nakul Chitnis, Rick Steketee
Malaria caused by a parasite, transmitted by mosquitoes

Preventable and treatable, inextricably linked with poverty

Endemic in 99 countries, 219 million cases, 660,000 deaths - 90% in Africa

Mortality rates fell by 26% around the world in the past decade
What is the next step to drive down malaria transmission?

- Successes challenged by funding plateau post-2011
- Important to identify cost-effective mix of malaria control interventions
Goal

To apply microsimulation modeling of malaria to field sites in different transmission settings to better understand transmission dynamics and explore different control interventions and strategies.

Objectives

1. **Apply OpenMalaria to discrete geographical areas**, and compare predictions with data collected from the different sites
   a. Rachuonyo South District, western Kenya
   b. Southern Province, Zambia

2. Investigate the simulated **epidemiology, disease burden, and economic impact** of current and future potential combinations of **malaria control interventions** in the study areas
Research question and field collaboration

- Site-specific model parameterization and validation
- Experiment design
- OpenMalaria simulation
- Analyze outputs
Driven by questions arising from existing trials, program implementation, and operational feasibility.

Research question and field collaboration

- Site-specific model parameterization and validation
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- Analyze outputs
Site-specific model parameterization and validation -> Experiment design -> OpenMalaria simulation -> Analyze outputs

- Stochastic simulation models of malaria based on the simulation of infections in humans
- Tracks health status of individuals at discrete time points

Research question and field collaboration

• OpenMalaria simulation

ID 1
ID 2
treat
new infection
increasing immunity
dead

T=1 T=2 T=3 T=4
Site-specific model parameterization and validation

Experiment design

OpenMalaria simulation

Analyze outputs

- Linked to a deterministic model of malaria transmission based on the mosquito feeding cycle
- Linked to models of interventions

Research question and field collaboration

openmalaria
A simulator of malaria epidemiology and control
**Research question and field collaboration**

1. **Site-specific model parameterization and validation**
2. **Experiment design**
3. **OpenMalaria simulation**
4. **Analyze outputs**

**EIR = entomological inoculation rate**

Number of infectious mosquito bites a person is exposed to over a certain period of time, i.e. one year.
Research question and field collaboration

- Site-specific model parameterization and validation
- Experiment design
- OpenMalaria simulation
- Analyze outputs

- EIR
- Parasite prevalence
- Uncomplicated episodes
- Hospitalizations
- Mortality
- Disability-adjusted life years (DALYs)

Cost effectiveness analysis
Objective 1a: Is OpenMalaria able to simulate the seasonal pattern of malaria transmission in Rachuonyo South District?
Measuring EIR through mosquito collection may not be the optimal way to define transmission in areas with low, unstable transmission.

EIR estimated by entomological survey in a neighboring district.

EIR estimated by serology from cohort, seasonal pattern estimated from rainfall.
**Objective 2a:** Are there alternative malaria control strategies that could have a larger impact on malaria burden in Rachuonyo South compared to the currently-implemented strategy?

1. Simulate impact* of different intervention combinations compared to a scenario with no intervention

- **Use of long-lasting insecticide treated mosquito nets (LLINs):** 56%, 80%
- **Indoor residual spraying (IRS):** 70%, 90%, April, May, June
- **Intermittent screen and treat of school children (IST):** 40%, 80%, 1 x term, 2 x term

2. Conduct costing exercise (and sensitivity analysis) for the case management system and additional interventions

<table>
<thead>
<tr>
<th>Cost per net distributed</th>
<th>Cost per person protected with IRS</th>
<th>Cost per child screened</th>
<th>Percentage of fevers accessing care</th>
<th>Cost of case mgt</th>
</tr>
</thead>
<tbody>
<tr>
<td>$8.52 ($4.26, $17.04)</td>
<td>$0.73 ($0.34, $1.36)</td>
<td>$6.32 ($3.16, $12.63)</td>
<td>61.8% (30.9%, 92.7%)</td>
<td></td>
</tr>
</tbody>
</table>

3. Attach costs to simulation results to conduct cost effectiveness analysis

Cost effectiveness ratio = \[
\frac{\text{total implementation costs} - \text{health system cost savings}}{\text{Outcomes averted (e.g. DALYs)}}
\]

*Reduction in parasite prevalence, number of uncomplicated episodes, hospitalizations, deaths and DALYs averted
• Transmission not low enough to take focus away from additional vector control in favor of a school-based intermittent screen and treat program

• Changing timing of IRS not as important as coverage

• Current intervention strategy is very cost effective

• Increasing use of nets is the most cost effective option; vector control more cost effective than adding an IST program to the current strategy.
Objective 1b and 2b: What is the simulated effect of alternative operational strategies for MSAT in Zambia’s Southern Province?
- Coverage the most important determinant of campaign success

- Adding PQ to DHAP not substantially more effective, although Ivermectin may be helpful
OpenMalaria able to aid in decision-making process for trial design and intervention evaluation when applied to operationally-feasible contexts

- In Rachuonyo South increased coverage of vector control most cost-effective simulated intervention; will need to be continued into elimination

- Coverage most important element for community-based drug administration campaigns; further investigation for Ivermectin
Conclusions and implications

To increase applicability of results and success of collaboration: appropriate use of the model to answer a question

- Logistical feasibility, insecticide and drug resistance, intervention acceptability
- Collaborations between field and modelers (essential, yet ad hoc)
  - Asking questions that are a) epidemiologically relevant, and b) model-applicable
- Current users = funders and academics (not yet program managers)
- Progress being made on cyber infrastructure to support use of models
Conclusions and implications

Understanding of role of models necessary in order to increase their use in evidence-based decision-making

• Gap exists in standard methodology for evaluating (and communicating!) uncertainty and validation

• Role of models: tool to communicate interactions between elements of a system; apply to specific questions
  
  • Making links between global predictions and site-specific recommendations
  
  • Should drive continued development of model features and tools
Acknowledgements

Swiss Tropical and Public Health Institute, HSRDM Unit
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Malaria Transmission Consortium
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OpenMalaria at SwarmFest

**Tuesday 10 AM**

Diggory Hardy and Nakul Chitnis: OpenMalaria, a Simulator of Malaria Transmission and Morbidity, and the Use of BOINC for High-throughput Computing

**Tuesday 12:15 PM**

Keynote: Greg Madey, Science Gateways: Hosting Agent-Based Models for Use by a Non-modeling Community