Health and Behavioral Impacts of Indoor Residual Spraying in Eritrea

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Introduction

The last decade or so has been one of great success in Eritrea’s fight against malaria.
Since the late 1990s, the National Malaria Control Program (NMCP) has promoted a new first line anti-malaria drug, and an integrated vector control program based mainly on insecticide treated nets (ITN), indoor residual spraying (IRS), and larval habitat management (LHM).

In 2008, Arianna Legovini led a team of researchers to Eritrea, and the NMCP showed interest in evaluating the impact of IRS (which is very expensive) in further reducing/eradicating the incidence of Malaria.
Introduction

This presentation combines the results of two papers, focusing on the epidemiological and behavioral aspects of the evaluation:

- Evaluating indoor residual spray for reducing malaria infection prevalence in Eritrea: results from a community randomized control trial, by Keating, Locatelli, Gebremichael, Ghebremeskel, Mufunda, Mihreteab, Berhane, and Carneiro

- Do Public Health Interventions Crowd Out Private Health Investments? Malaria Control Policies in Eritrea, by Carneiro, Locatelli, Ghebremeskel, and Keating
What we do

- Analyze the health and behavioral consequences of implementing IRS, on top of existing ITN and LHM strategies.
- Study a cluster-RCT taking place in the most malarious region of Eritrea: Gash Barka.
  - Originally, 58 treatment and 58 control villages.
  - In practice, there were some changes...
  - Implement a post-treatment household survey with blood testing (RDT).
  - Spraying takes place in June-July 2009. Survey takes place in October 2009 (transmission season).
Epidemiological Findings

- Malaria prevalence is low, even though the study targeted the most malarious villages.

- **We did not detect a significant impact of IRS on malaria prevalence.**
  - Given that malaria prevalence is low, any impact will also be low, and our study may not have enough power to detect it.
  - Still, we would probably have enough power to detect a complete eradication of malaria, if that was the result of the IRS campaign.
Behavioral Findings

- Do public health investments crowd-out private health investments? IRS could crowd out ITN use (there is a big literature on this general topic).
- This would occur if IRS and ITN are substitutes, and if individuals have perfect information.
- Instead, we find that ITN ownership and use is higher in villages with IRS.
- With uncertainty and/or imperfect information, IRS may induce a change in awareness/beliefs about malaria, causing an increase in ITN ownership and use, even if they are substitutes.
  - This is a (simple but) new result.
Suppose you thought malaria was gone, but this guy showed up at your place…
Intervention

- The intervention consists of government organized spraying of all houses in treatment villages (DDT), before the malaria season (June/July 2009).
  - A small number of houses were not sprayed because no one was home or because they refused spraying.
- The universe consists of villages identified by the NMCP as being especially malarious villages in Gash Barka, which is the most malarious region in the country.
  - 106 total, 58 treatment, 58 control (57 in practice)
We faced practical difficulties in the randomization process, but which at the end do not seem problematic.

An initial list of villages was provided for the randomization. Treatment and control villages had to be at least 5 km apart, so in the 2 cases where this did not happen, the closest village at least 5 km apart was chosen as control.

Later we found that the list was dated from 2003, and since then villages have moved or merged with other villages. They were replaced with the closest village in the area.
Data

Data collection had three components:

- Household Survey
- Rapid Diagnostic Test (RDT)
- Entomological Survey (mosquito lamps)

Orotta School of Medicine / NMCP Staff

The household survey and RDT took place in October 2009, right after the peak of the transmission season.

The collection of mosquitoes took place roughly a month after.

Funded through a World Bank grant.
More practical difficulties

- Sample size (870=58*15 treatment households, and 870 control) calculated to detect a reduction of 10.5% points (alpha = 5%) in malaria prevalence from a baseline of about 15% (80% power, ICC = 0.3).
  - We will see that this was WAY OFF, but we did not have adequate data at the time
- Because of delays and difficulties in procurement, the collection of mosquito data occurred too late, when mosquitoes were no longer present – it was essentially useless.
Randomization Checks

- There is no baseline data, so the randomization checks use variables that seem predetermined a priori:
  - Age, gender, education, literacy, marital status, tribe, religion, household size, house characteristics

- We check balancing variable by variable, and also perform a joint test:
  - \[ Y = a + bT + u \]
  - \[ \text{H}_0 : b = 0 \]
  - \[ \text{Pr}(T=1|X) = \Phi(X^*c) \]
  - \[ \text{H}_0 : c = 0, \text{ where } c \text{ is a vector} \]
### Randomization Checks

**Table 3: Randomization checks – Individual Variables**

<table>
<thead>
<tr>
<th>Variables (Y)</th>
<th>Treatment</th>
<th>Control</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ALL HOUSEHOLD MEMBERS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1- Female</td>
<td>0.52</td>
<td>0.52</td>
<td>-0.0040</td>
</tr>
<tr>
<td></td>
<td>(0.50)</td>
<td>(0.50)</td>
<td>(0.0113)</td>
</tr>
<tr>
<td>2- Usually lives here</td>
<td>0.98</td>
<td>0.98</td>
<td>0.0062</td>
</tr>
<tr>
<td></td>
<td>(0.13)</td>
<td>(0.16)</td>
<td>(0.0049)</td>
</tr>
<tr>
<td>3- Stayed here last night</td>
<td>0.97</td>
<td>0.95</td>
<td>0.0137</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.21)</td>
<td>(0.0086)</td>
</tr>
<tr>
<td>4- Age</td>
<td>22.34</td>
<td>22.00</td>
<td>0.3456</td>
</tr>
<tr>
<td></td>
<td>(19.52)</td>
<td>(19.18)</td>
<td>(0.4924)</td>
</tr>
</tbody>
</table>

**P-value [variables 1–4]** 0.25
Randomization Checks

<table>
<thead>
<tr>
<th>Variables (Y)</th>
<th>Treatment</th>
<th>Control</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RESPONDENTS ONLY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5- Age</td>
<td>42.05</td>
<td>41.43</td>
<td>0.6157</td>
</tr>
<tr>
<td></td>
<td>(15.01)</td>
<td>(15.25)</td>
<td>(0.8926)</td>
</tr>
<tr>
<td>6- Ever attended school</td>
<td>0.19</td>
<td>0.19</td>
<td>0.0072</td>
</tr>
<tr>
<td></td>
<td>(0.39)</td>
<td>(0.39)</td>
<td>(0.0339)</td>
</tr>
<tr>
<td>7- Only primary school</td>
<td>0.74</td>
<td>0.78</td>
<td>-0.0373</td>
</tr>
<tr>
<td></td>
<td>(0.44)</td>
<td>(0.41)</td>
<td>(0.0527)</td>
</tr>
<tr>
<td>8- Literate</td>
<td>0.18</td>
<td>0.20</td>
<td>-0.0151</td>
</tr>
<tr>
<td></td>
<td>(0.39)</td>
<td>(0.40)</td>
<td>(0.0321)</td>
</tr>
<tr>
<td>9- Muslim religion</td>
<td>0.84</td>
<td>0.78</td>
<td>0.0601</td>
</tr>
<tr>
<td></td>
<td>(0.37)</td>
<td>(0.42)</td>
<td>(0.0678)</td>
</tr>
<tr>
<td>10- Tigre tribe</td>
<td>0.57</td>
<td>0.40</td>
<td>0.1666*</td>
</tr>
<tr>
<td></td>
<td>(0.50)</td>
<td>(0.49)</td>
<td>(0.0843)</td>
</tr>
<tr>
<td>11- Married</td>
<td>0.93</td>
<td>0.94</td>
<td>-0.0125</td>
</tr>
<tr>
<td></td>
<td>(0.26)</td>
<td>(0.24)</td>
<td>(0.0133)</td>
</tr>
</tbody>
</table>

P-value [variables 5–6,8–11] 0.16
Randomization Checks

- Treatment and Control groups are balanced across a variety of characteristics (the one exception is Tigre tribe).

- We have analyzed two other types of variables: household size and housing conditions. The sample is balanced.
Empirical Models

- Depending on whether the outcome is continuous or discrete we estimate:
  - $Y = a + bT + X^c + u$
  - $Pr(Y=1|T,X) = \Phi(a + bT + X^c)$
    - $\Phi$ is the cdf of the standard normal
    - Cluster standard errors at village level

- Three specifications: no controls, some controls (Tigre, Muslim, Subzone), many controls (variables in randomization checks).

- Outcomes: malaria prevalence (RDT), net ownership and use, knowledge/beliefs.
## Impacts on Malaria Prevalence

| Variables          | Treatment | Control | \(E(Y|T=1, X) - E(Y|T=0, X)\) No Regressors | \(E(Y|T=1, X) - E(Y|T=0, X)\) Basic Regressors |
|--------------------|-----------|---------|---------------------------------------------|---------------------------------------------|
| Positive RDT       | 0.006     | 0.005   | 0.001                                       | 0.001                                       |
| (0.077)            | (0.070)   |         | (0.003)                                    | (0.002)                                    |
| Observations       | 2,872     | 2,630   | 5,502                                       | 4,664                                       |
Impacts on Malaria Prevalence

- Malaria parasite infection prevalence (measured using RDT) was 0.5%.
  - Very low base, IRS will not do much, and it will be difficult to detect.
  - Power calculations assumed 15% baseline prevalence (based on facility level data).
- Effect of IRS on prevalence is basically zero
- If IRS eradicated malaria we would probably be able to detect that.
Impacts on net ownership and use

| Variables                                      | Treatment | Control | \(E(Y|T)\) |
|------------------------------------------------|-----------|---------|-------------|
| 1. Number of nets owned by household           | 1.774     | 1.575   | 0.200*      |
|                                               | (1.279)   | (1.207) | (0.110)     |
| 2. Number of ITNs owned by household           | 1.444     | 1.278   | 0.166*      |
|                                               | (1.206)   | (1.126) | (0.0963)    |
| 5. Number of observed nets used the night before| 1.384     | 1.164   | 0.220**     |
|                                               | (1.214)   | (1.054) | (0.0990)    |
| 6. Number of observed nets left unused the night before | 0.676 | 0.736 | -0.0600 |
|                                               | (0.993)   | (1.001) | (0.0763)    |
| 7. “Full” net coverage (≥ 1 net per 1.5 household members) | 0.193 | 0.162 | 0.031 |
|                                               | (0.395)   | (0.369) | (0.025)     |
Impacts on net ownership and use

- There is an increase in the number of nets owned, which are essentially ITNs.
- There is an increase in the number of nets being used.
- These are not enormous effects but they are significant.
- These are odd results in light of the standard model, if we assume nets and IRS are substitutes.
  - IRS and nets are complements?; or
  - Imperfect information and changing beliefs?
## Impacts on Information

<table>
<thead>
<tr>
<th>Variables</th>
<th>Treatment</th>
<th>Control</th>
<th>No Regressors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mosquitoes mentioned among malaria vectors</td>
<td>0.908</td>
<td>0.854</td>
<td>0.0541**</td>
</tr>
<tr>
<td></td>
<td>(0.289)</td>
<td>(0.353)</td>
<td>(0.0213)</td>
</tr>
<tr>
<td>2. Malaria is a problem in community</td>
<td>0.726</td>
<td>0.670</td>
<td>0.0564</td>
</tr>
<tr>
<td></td>
<td>(0.446)</td>
<td>(0.471)</td>
<td>(0.0442)</td>
</tr>
<tr>
<td>3. Children mentioned among most affected by malaria</td>
<td>0.863</td>
<td>0.788</td>
<td>0.0744***</td>
</tr>
<tr>
<td></td>
<td>(0.344)</td>
<td>(0.409)</td>
<td>(0.0248)</td>
</tr>
<tr>
<td>4. Pregnant women mentioned among most affected</td>
<td>0.367</td>
<td>0.365</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(0.482)</td>
<td>(0.482)</td>
<td>(0.0403)</td>
</tr>
</tbody>
</table>
Impacts on Information

- Malaria is still perceived as a problem in spite of the very low prevalence of infection.
- Substantial exposure to information campaigns, and substantial awareness about basics of malaria. But information campaigns not correlated with IRS (not in table).
- IRS causes an increase in awareness/beliefs that mosquitoes are important for malaria transmission and that children are particularly affected by malaria.
Discussion

- We observe that IRS:
  - had no impact on malaria prevalence.
  - increased ITN ownership and use.
  - raised awareness about some important issues related to malaria transmission.

- We argue that IRS led to an increase in awareness which in turn caused an increase in ITN ownership and use.
  - If there is uncertainty, IRS-like campaigns can lead to an update in beliefs.

- We can formalize this with a simple model.
A Simple Model

- N workers have time endowment T, which is reduced to T-t upon infection, which occurs with probability $\pi$ in there is no ITN or IRS.
- There are two technologies which affect $\pi$: $\Phi$ (ITN) and $\Psi$ (IRS).
  - $\Phi$ is individual choice, $\Psi$ is publicly provided
  - $\pi^\Phi = \pi - \alpha^\Phi$, $\pi^\Psi = \pi - \alpha^\Psi$, $\pi^{\Phi \cup \Psi} = \pi - \alpha^\Theta$, $\alpha^\Theta > \{\alpha^\Phi, \alpha^\Psi\}$
- Choose $\Phi$ to $\text{Max } \Phi \ E(U|\Psi)$
  - $(\Phi, \Psi)$ are indicator variables
  - $U = Y - \Phi^*d$; $d$ is disutility of using the net (varies across individuals); $Y = (T-t)w$
Perfect Information

Use ITN if:
- $W[(1- \pi)T+\pi(T-t)] < W[(1- \pi^\Phi)T+ \pi^\Phi(T-t)] - \Phi^*d$
- $W[(1- \pi^\Psi)T+ \pi^\Psi(T-t)] < W[(1- \pi^\Phi \Psi)T+ \pi^\Phi \Psi(T-t)] - \Phi^*d$

Question: $\Pr(\Phi=1|\Psi=1) < \Pr(\Phi=1|\Psi=0)$?

It depends:
- $\alpha^\Theta \leq \alpha^\Phi + \alpha^\Psi$ implies that $\Pr(\Phi=1|\Psi=1) \leq \Pr(\Phi=1|\Psi=0)$
- $\alpha^\Theta \geq \alpha^\Phi + \alpha^\Psi$ implies that $\Pr(\Phi=1|\Psi=1) \geq \Pr(\Phi=1|\Psi=0)$

The first case is the most standard – under those conditions we would expect ITN use to fall with IRS.
- But the data shows the opposite
Imperfect Information

- π is unknown. To simplify, say π={0,λ}.
- Individuals have uniform prior over Pr(π=λ)
- Individuals assume government knows π, and that: Pr(Ψ=1| π=λ) ≥ Pr(Ψ=1| π=0)
- If individuals are Bayesian, their posterior on π is such that Pr(π=λ|Ψ=1) ≥ Pr(π=λ|Ψ=0)
- Ψ reduces the chances of infection, but increases subjective probability of infection
- Even when Ψ and are Φ are substitutes we can have Pr(Φ=1|Ψ=1) ≥ Pr(Φ=1|Ψ=0)
Summary

We study the impact of IRS on malaria prevalence and ITN ownership and use, in a low-transmission setting.

IRS has no impact on prevalence, but baseline levels are (probably) tiny.

IRS does not crowd out ITN ownership and use
- ITN and IRS are complements? Probably not.
- IRS leads to change in beliefs. Perhaps – there is suggestive evidence that this can happen.

This is a (simple but) new result. It illustrates a mechanism which is potentially at work in other settings.