A mathematical model for the prospects of trachoma elimination through mass treatment targeted at children

Laing Lourens
BSc Mathematical Statistics (NMMU)
BSc Hons Biomathematics (Stell.)
MIT Big Data Science (UP) *
Trachoma

- What is it
  - Leading infectious cause of blindness
  - inside of the eyelid may be scarred so severely that the eyelid turns inward and the lashes rub on the eyeball, scarring the cornea

![Images of trachoma symptoms](image-url)
Trachoma

• How does it spread?
  – Direct contact with discharge from eyes, nose and throat of infected persons
  – Aerosolized pathogens from nasal infections
  – Active transfer of bacterium due to flies

• Prevalence
  – 21.4 million active infections
  – 1.2 million suffering blinding
  – Endemic in 53 countries as of 2012
Trachoma

• Prevalence
  – Highly prevalent in children
  – Children form core group for transmission

• WHO Eradication Strategy
  – GET 2020
  – SAFE strategy
  – Mass Drug Administration:
    Oral dose of Azithromycin (~95% efficacy)
  – ANNUAL treatment of ALL individuals if ...
Problem Statement

• Can antibiotic treatment targeted at children alone eliminate trachoma infection from an entire community?
Data

- **Trachoma Amelioration in Northern Amahara (TANA) study:**
  - Investigation of the impact of 1 year of *quarterly* single dose oral azithromycin treatment in children aged 1-9 on adult trachoma prevalence
  - 24 subkebeles in randomized trial with control group

<table>
<thead>
<tr>
<th></th>
<th>Child treatment group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Child prevalence</strong></td>
<td>3.6% (95% CI: 0.8–6.4)</td>
<td>45.6% (95% CI: 36.7–54.5)</td>
</tr>
<tr>
<td><strong>Adult prevalence</strong></td>
<td>8.2% (95% CI: 5.1–11.4)</td>
<td>12.7% (95% CI: 8.9–16.6)</td>
</tr>
</tbody>
</table>
Model

- Susceptible-infected-susceptible (SIS)

- 2 age classes
  - Adults
  - Children
Parameters

Recovery
\[ \gamma_c y_c = r_1 \]
\[ \gamma_a y_a = r_2 \]

Transmission
\[ (\beta_{a\rightarrow c} \frac{y_a}{N_a} + \beta_{c\rightarrow c} \frac{y_c}{N_c}) x_c = r_3 \]
\[ (\beta_{a\rightarrow a} \frac{y_a}{N_a} + \beta_{c\rightarrow a} \frac{y_c}{N_c}) x_c = r_4 \]

\( y_a \): Infected Adults
\( y_c \): Infected Children
\( x_c \): Susceptible Children
\( x_a \): Susceptible Adults
\( N_a \): Adult Population
\( N_c \): Children Population
Simulation

- Each village simulated for 100 months to allow the model to reach a state of endemic quasi-equilibrium
  - One absorbing state (epidemic extinction)

- After reaching quasi-equilibrium:
  - Simulated mass administration of azithromycin to children
  - Months 0, 3, 6 and 9
  - Repeated simulations averaged to derive the estimated adult and child prevalence
## Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial Value</th>
<th>Final Value</th>
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</thead>
<tbody>
<tr>
<td>Adult recovery $\gamma_a$</td>
<td>0.25 yr</td>
<td>0.64 yr</td>
</tr>
<tr>
<td>Child recovery $\gamma_c$</td>
<td>0.083 yr</td>
<td>0.23 yr</td>
</tr>
<tr>
<td>Adult $\rightarrow$ child transmission $\beta_{ac}$</td>
<td>0.125 yr</td>
<td>0.43 yr</td>
</tr>
<tr>
<td>Child $\rightarrow$ child transmission $\beta_{cc}$</td>
<td>0.125 yr</td>
<td>0.32 yr</td>
</tr>
<tr>
<td>Child $\rightarrow$ adult transmission $\beta_{ca}$</td>
<td>0.0625 yr</td>
<td>0.34 yr</td>
</tr>
<tr>
<td>Adult $\rightarrow$ adult transmission $\beta_{aa}$</td>
<td>0.0625 yr</td>
<td>0.18 yr</td>
</tr>
<tr>
<td>Odds of consecutive treatment</td>
<td>1</td>
<td>3.58</td>
</tr>
<tr>
<td>Antibiotic efficacy</td>
<td>0.9</td>
<td>0.98</td>
</tr>
</tbody>
</table>
Results

Trachoma Prevalence with Mass Treatment

Prevalence

Years

Adults
Children
TANA children
TANA adult
Conclusion

- Quarterly MDA campaigns administered for 10 years can greatly reduce, possibly eliminate trachoma in adults

- Transmission involving children more likely than adults

- Child recovery much slower than adults
Thank you

Questions?