Thinking about numbers: Mathematical models and the control of HIV

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The purpose of models is not to fit the data but to sharpen the question. Karlin, S.
Modelling for modellers

- Stay as close to the data as you can
- Put in as much biology as you can
- Keep it simple
Modelling for non-modellers

- Examine the data carefully
- Question all the assumptions
- Assume that the modellers know what they are doing
The case reproduction number

$R_0$

The number of secondary cases you get from one primary case of infection
Why is $R_0$ so important?

1. It tells us if things are getting better or worse
   \[ R_0 > 1: \text{prevalence increases exponentially} \]
   \[ R_0 < 1: \text{prevalence falls exponentially} \]

2. It tells us the magnitude of the control problem. If we reduce transmission by a factor of $R_0$ we will eventually eliminate the disease.

3. It tells us the expected prevalence if we do nothing and the vaccination coverage needed for elimination
   \[ P = \frac{(R_0 - 1)}{R_0} \]

http://en.wikipedia.org/wiki/Basic_reproduction_number
HIV in Botswana
Trends, estimates and projections
4 stages of infection to get the right survival
Doubling time \( \approx 1.5 \) yrs
Life expectancy \( \approx 10 \) yrs
\( R_0 \approx 10/1.5 \approx 7 \)

Heterogeneity in risk
\[ \lambda \rightarrow \lambda \left(1 - \frac{P}{P^*}\right) \]

Change in behaviour

Anti-retroviral therapy
Doubling time $\approx 1.5$ yrs
Life expectancy $\approx 10$ yrs
$R_0 \approx 10/1.5 \approx 7$

Heterogeneity in risk
$$\lambda \rightarrow \lambda \left(1 - \frac{P}{P^*}\right)$$

Change in behaviour

Initial prevalence
How infectious are people on ART?
Viral load and transmission

Attia 2009 AIDS; Gaolathe 2016 Lancet

Viral load/mL

Transmissions/yr

0.00001
0.00010
0.00100
0.01000
0.10000
1.00000
10 100 1000 10000 100000 1000000 10000000

10 100 1,000 10,000 100,000 1,000,000

93% 3.4% 3.5%

97%

99.7%

Botswana

Virions/mL

Attia 2009 AIDS; Gaolathe 2016 Lancet
Constant effort  

90-90-90 + Prevention
Botswana

Prevalence HIV & ART

Incidence & Mortality

P
I
M
A

Prevalence HIV & ART

Incidence & Mortality

1980 2000 2020 2040

Botswana
What does HIV do to TB?
TB and HIV: Gold Miners in South Africa

<table>
<thead>
<tr>
<th>Year Interval</th>
<th>HIV- %</th>
<th>HIV+ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-1994</td>
<td>1.0</td>
<td>2.2</td>
</tr>
<tr>
<td>1995-1997</td>
<td>1.1</td>
<td>5.9</td>
</tr>
<tr>
<td>1998-1999</td>
<td>1.1</td>
<td>9.4</td>
</tr>
</tbody>
</table>

IRR: ~10

No change

IRR: ~2

No change

Corbett *et al.* *Journal of Infectious Diseases* 2003; 188: 1156-63
Impact of HIV and ART on TB

Prevalence 1.1π 1.4π 1.8π 2.4π 1.06η
Incidence 1.1η 2.3η 4.6η 9.3η 1.3η

Three variable parameters: Incidence pre-HIV, rate of increase with HIV-progression, reduction in disease duration
Botswana

Cost of treatment and prevention

HC on ART
ART
Testing
HC not on ART
Deaths


US$1.5 Bn 2016 to 2030 or US$150 M p.a.
Impact of treatment and prevention in Mozambique

GOALS model ART
50% coverage
20% as infectious

My model ART
65% coverage
35% as infectious

Korenromp et al. PLOS 2015
Thank you