Practicals: An introduction to TB modelling

Practical 2
Conflict of interest disclosure

I have no, real or perceived, direct or indirect conflicts of interest that relate to this presentation
Practicals: An introduction to TB modelling

Aims

• To illustrate questions which might be addressed using mathematical models

• To give you insight into what data and assumptions models might need
Practical 2: Modelling the impact and cost effectiveness of TB interventions

Objectives
By the end of this practical, you should:

• Know how you might estimate the impact of improved diagnostics.
• Describe and interpret different measures of cost-effectiveness.
Overview

• Quick introduction to the model
• Exploring the impact of improved diagnostics on the number of cases prevented
• Calculating the cost and cost-effectiveness of introducing the new diagnostic
General structure of the model

Susceptible to infection → Latently infected (fast progressors after infection) → Latently infected (slow progressors) → Infectious (smear positive) → Recovered → Infectious (smear negative) → Latently infected (fast progressors after re-infection) → Latently infected (slow progressors) → Infectious (smear negative) → Recovered → Infectious (smear positive) → Latently infected (fast progressors after re-infection)
Latently infected (slow progressors)

Latently infected (fast progressors after re-infection)

Latently infected (fast progressors after infection)

Recovered

Infectious (smear negative)

Infectious (smear positive)

Susceptible to infection

Smear-negative

30% (X-ray)

Access to diagnostic

Smear-positive

80% (+ive X-ray)

Successful diagnosis:

85% Start treatment

75% Recovered (after successful treatment)

Assumed pre-existing diagnostic pathway
The pre-existing and new diagnostic pathways

- Susceptible to infection
- Latently infected (fast progressors after infection)
- Latently infected (slow progressors)
- Infectious (smear negative)
- Infectious (smear positive)
- Recovered

Access to diagnostic

- Smear-negative: 100% (New diagnostic)
- Smear-negative: 30% (X-ray)
- Smear-positive

Successful diagnosis

- 80% (+ive X-ray)
- 70% (New diagnostic)
- 100%

Start treatment

- 85%
- 75%

Recovered (after successful treatment)

30% (X-ray)

100% (New diagnostic)

100% (New diagnostic)
Q1 **Short term** – small impact expected, as the intervention does not directly prevent cases (only leads to increased diagnosis.

**Long term** – an increased impact is expected due to the indirect effect of improved diagnostics, i.e. ↓ in the duration of infectiousness, leading ↓ in number of infections (and cases) generated by each case.
### Answers

**Step 1, page 4**

<table>
<thead>
<tr>
<th></th>
<th>Without the intervention</th>
<th>With the intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>End of 2014 (1 year)</td>
<td>End of 2023 (10 years)</td>
</tr>
<tr>
<td>TB incidence per 100,000 per year</td>
<td>197</td>
<td>197</td>
</tr>
<tr>
<td>TB mortality rate per 100,000 per year</td>
<td>51</td>
<td>47</td>
</tr>
<tr>
<td>Annual risk of infection (%/year)</td>
<td>2.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>
### Answers

Step 2&3, page 4

<table>
<thead>
<tr>
<th></th>
<th>Without the improved diagnostic</th>
<th>With the improved diagnostic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of TB cases in 2014</td>
<td>193</td>
<td>192</td>
</tr>
</tbody>
</table>

Number of cases prevented by introducing the new diagnostic in 2014 = 193 - 192 = 1

Q2. Over a 10 year period, might expect to prevent at least $10 \times \text{number of cases prevented over 1 year} = 10 \text{ cases}$
Number of cases prevented over 10 years by introducing the new diagnostic in 2014 = 1969 - 1906 = 63
Q3. Number of cases predicted over a 10 year period is much greater than $10 \times$ number of cases prevented over 1 year.

This is due to the indirect effect of improved diagnostics:

↓ in the duration of infectiousness leads to:
  ↓ in the number of infections generated by each case;
  ↓ in the risk of infection;
  ↓ in the number of individuals at risk of progression to disease
Answers

Q4 (optional). If the effective contact rate is very high (20/year), the intervention prevents 98 cases. i.e. higher than when the effective contact rate is 15 *per year.*

This is due to the *increased* background incidence
Q5. Introduction of new test leads to:
• ↑ in the number of diagnoses in smear-negatives.
  – This is due to the increased number of cases being detected because of the increased sensitivity of the test vs X-ray
• As TB incidence ↓, the number of diagnoses in smear-negative cases also falls.
• ↓ incidence of smear-positive TB, because of the reduction in the number of new infections (and cases) resulting from each infectious case
Graph 3: The number of TB diagnoses per week following the introduction of the new diagnostic in 2014.
After the new diagnostic is introduced:

- No examinations are carried out using X-ray
- The new diagnostic is offered to all smear-negative cases (vs 30% of cases being offered X-ray before the intervention)
  - Therefore, the number of new diagnostic tests used equals the number of smear examinations in smear-negative cases.
- Over time, the numbers of all tests used in the new algorithm declines as the TB incidence ↓.
Graph 4: Predictions of the weekly numbers of smear examinations and tests
Q6. The cost associated with the intervention is much greater than the cost of continuing with the current diagnostic algorithm ($249,256 compared to $86,423).

The increased cost is a consequence of:

- Higher cost of the new test compared to X-ray ($20 vs $10)
- Increased proportion of smear-negative cases offered the new test compared X-ray (100% vs 30%).
Q7a). The average cost effectiveness ratio (ACER) is:

\[
\text{Total cost of intervention/Total impact of intervention}
\]

The ACER of the current algorithm = $58/case
The ACER of the new diagnostic test = $147/case
Answers

Q7b). The new intervention lies in the upper right corner of the cost effectiveness plane

It is more effective than the current algorithm but costs more per case diagnosed
Answers

Q7c). To assess which intervention was most cost-effective you would need to know:

What are the health impacts of diagnosing more cases?

What is the “willingness to pay” threshold?
Answers

Q8 (optional). If the population was larger the cost per diagnosis would be lower:

• ↑ in the population leads to ↑ number of cases
• Fixed costs associated with the new test are divided between more individuals
• Cost per diagnosed case ↓
Q9 (optional). Discounting means intervention impacts which occur in the future are worth less than those that occur sooner i.e:

Case averted in 10 years time is worth much less than a case averted tomorrow

If discounting of impacts was included:
- Impact of intervention ↓
- Cost of intervention remains the same
- ACER of the new diagnostic test ↑
Practical 2: Modelling the impact and cost effectiveness of TB interventions

Objectives

By now, you should hopefully:

• Have a conceptual understanding of how you might incorporate interventions into a mathematical model for TB.

• Know how you might estimate the impact of improved diagnostics.

• Be able to describe and interpret different measures of cost-effectiveness
Practicals: An introduction to TB modelling

Having done the two practicals, you should now:
• Be aware of questions which might be addressed using mathematical models
• Have insight into what data and assumptions models might need…