Incorporating health systems into epidemiological models of TB case detection: what are the major considerations?

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Introduction

This talk:

- Focus on interventions changing case detection
- Focus on epidemiological impact (& mainly transmission)
- Conceives of case detection as an emergent property of patients, providers, and their interactions

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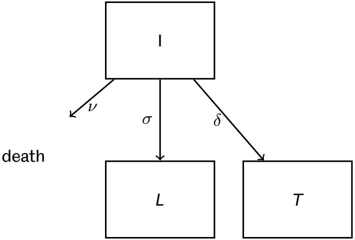
I'm not speaking based on lots of experience! Some reflections on unpacking detection in relation to health systems.

Simple detection



- death (ν), self-cure (σ), detection & treatment (δ)
- Probability of detection:

$$p = \frac{\delta}{\nu + \sigma + \delta}$$

- Without detection, 50% CFR & $T = 3$ year duration

$$\rightarrow \nu = \sigma \;\&\; (\nu + \sigma) = T^{-1}$$

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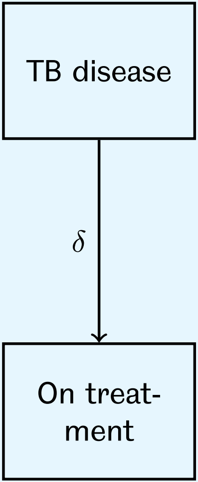
Simple detection

How might δ depend on more concrete quantities?



Model whole process from TB disease to on treatment by an overall rate (competing hazard), δ.
If all those starting treatment must be diagnosed, this must be proportional to the diagnostic sensitivity:

$$\delta = \text{frequency of diagnostic attempts}$$
$$\times\ \text{sensitivity of diagnostic}$$

Under a change in diagnostic sensitivity:

$$\delta \to \frac{s_{new}}{s_{old}}.\delta$$

But...

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Simple detection

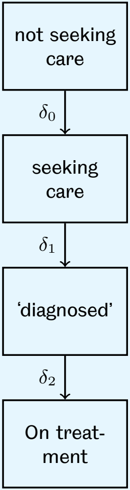
Care-seeking:

- Typical answer to question at clinic:
  'How long have you had symptoms?'
  ≈ 1 month
- Typical ratio prevalence/incidence $\sim$ duration
  ≈ 1 year

Ignoring the delay to care-seeking may over-estimate the impact of passive (i.e. clinic-based) improvements to detection.

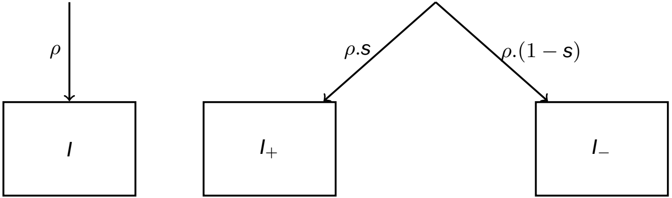
Simple detection

How might δ depend on more concrete quantities?



- δ_0 is a rate associated with symptom progression.
- δ_1 involves rate of care-seeking and diagnostic sensitivity.
- δ_2 is associated with the delay to starting treatment.

Smear status



Force-of-infection (proportional to prevalence):

$$\lambda = \beta.\frac{I}{N} \qquad\qquad \lambda = \beta.\frac{(I_+ + f.I_-)}{N}$$

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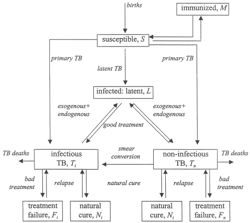
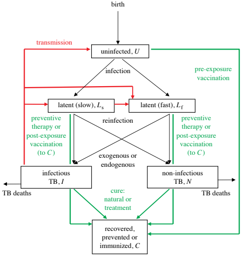
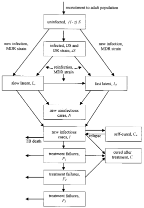
Model structure depends on question...



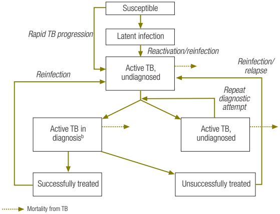
(a) Dye et al., 1998



(b) Dye et al., 2008



(c) Dye et al., 2000



(d) Dowdy et al., 2009

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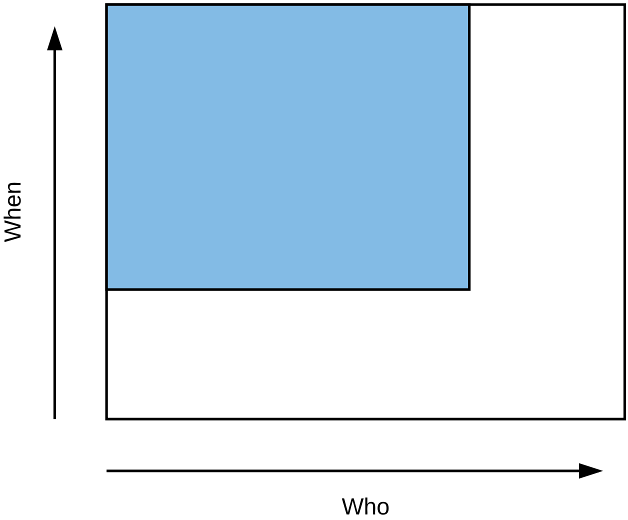
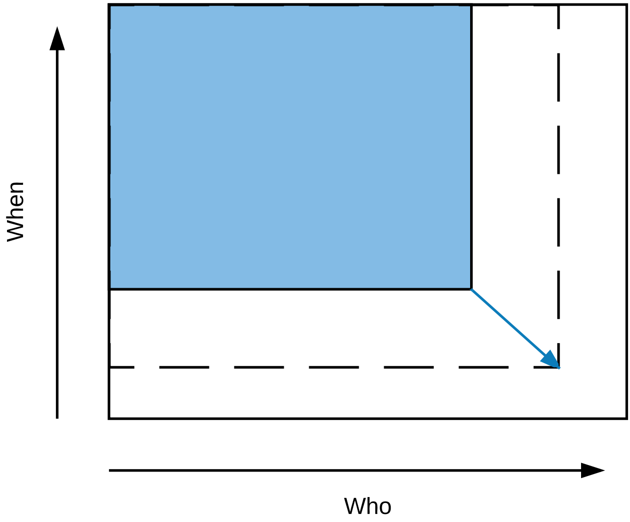
Case detection



Case detection



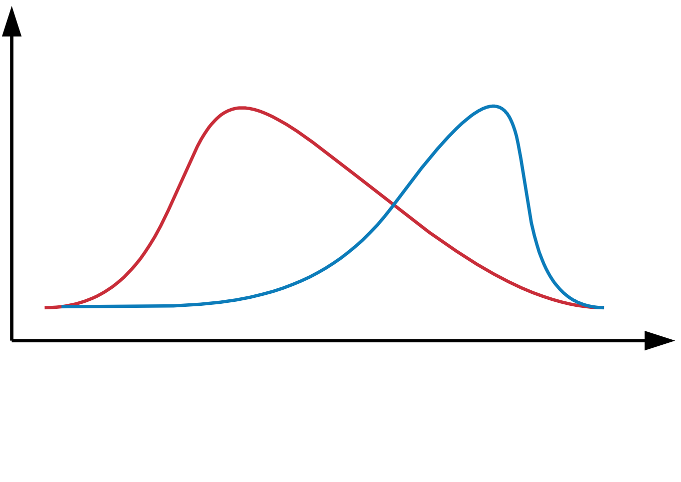
Case detection

Central problem:

Understand how concrete, detailed changes in health systems translate into changes in case detection and epidemiological impact.

Heterogeneity in time

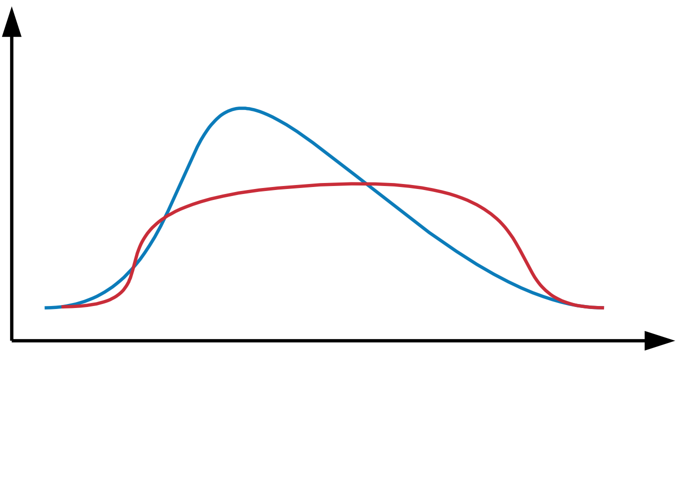
Natural history of infectiousness & care-seeking



Bad...

Heterogeneity in time

Natural history of infectiousness & care-seeking



Better...

Heterogeneity in type

Individual characteristics $\leftrightarrow$ care-seeking & infectiousness

- infectiousness (e.g. smear status, number of contacts)
- age
- sex
- TB treatment history
- comorbidity (e.g. HIV)
- location
- SES
- heterogeneity in time course by type...
- mixing between groups...

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- heterogeneity in time course by type...
- mixing between groups...

Understand proportion of transmission by type
& who the intervention will affect.

Provider-side considerations

Factors relevant to patient interactions:

- private/public
- level of facility
- location
- referral pathways
- capacity/logistics
- delays
- provider behaviour (under intervention)

Patient pathways

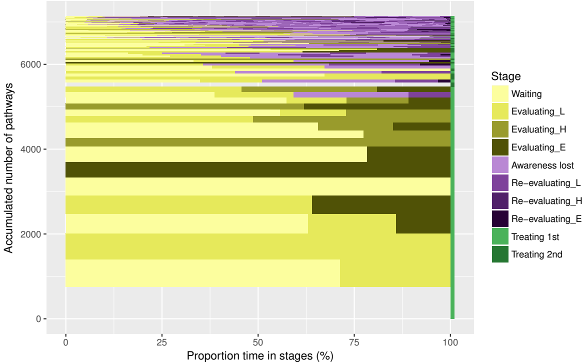

Figure: Chu-Chang Ku's analysis of pre-tx pathways in Taiwan

Patient pathways

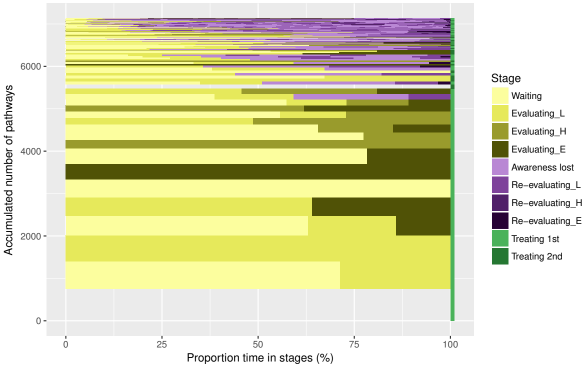

Figure: Chu-Chang Ku's analysis of pre-tx pathways in Taiwan

- Interaction between patients and health system generates often complex pathways
- A majority of relevant patient-system interactions are with a minority of patients
- How do interventions influence these pathways & what contribution do these pathways make to transmission?

Nosocomial transmission

Figure: Singh JA, Upshur R, Padayatchi N (2007) XDR-TB in South Africa: No Time for Denial or Complacency. PLoS Med 4(1): e50. https://doi.org/10.1371/journal.pmed.0040050

Technical challenges

Yes, many data challenges (covered elsewhere).

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Additional challenges:

- Modelling health systems implies wanting to inform a practical policy question in a particular setting.
- Many of the complex aspects aluded to above would suggest use of an individual/agent-based model

$\rightarrow$ Problematic, especially including transmission (capacity, manageability,...)

Technical challenges

Potential solutions:

- Computational approaches
  - Easily-specifiable hybrid modelling framework
  - Flexible approximation generation
- Model simplification
  - Deriving adequate simplified model structures & parameterizations
  - Understanding when existing model (structures) are OK & how to parametrize

This last has particular relevance to country-level modelling using generic tools for GFATM applications etc.

Conclusion

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Some factors to consider:

- who interacts with which services and when
  - relationship to likely contribution to transmission
  - what those interactions look like: relevant to intervention?
- Behaviour
  - patients
  - providers
  - changes in response to intervention
- potential for (changes in) nosocomial transmission

Data and implementation challenges require systematic approach to simplification for a given setting & intervention.