Modeling Intervention Strategies for United States TB Control

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Introduction

- Epidemiological models describe disease outbreaks.
- Compartmental Differential Equation models are common and rigorous epidemiological models.
- The Hill Model is a complex compartmental model of tuberculosis (TB) in the United States (US).

The Basic Hill Model

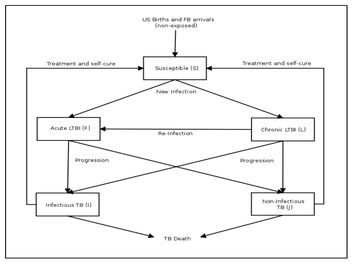

Figure: A flow chart representing the compartments of the Hill Model.

Populations:

- US Born Individuals (USB)
- Foreign Born Individuals (FB)

Individuals also leave the model due to natural death.

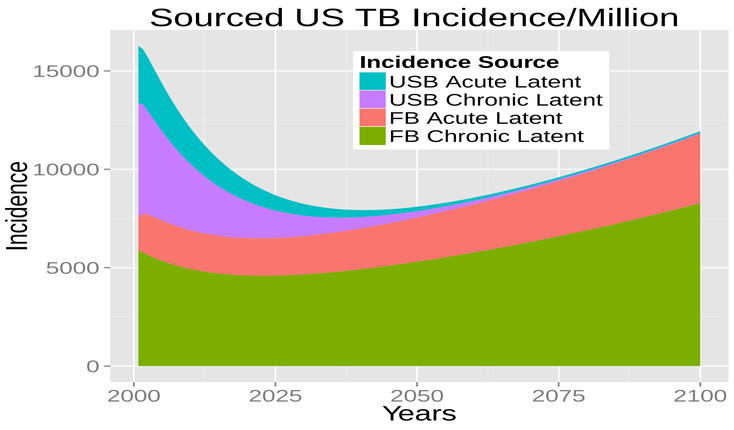

Figure: The source population of US TB incindecence

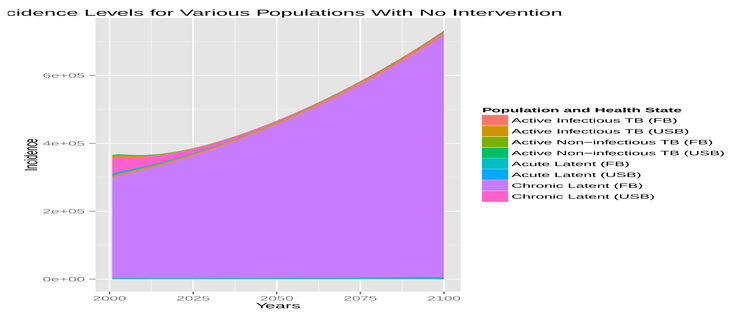

Figure: ~~New cases per year of various types of TB in the US.~~

Analyzing US TB Reduction Strategies

- Implemented in R, with various numerical DE solvers.
- Tracks US Health Care System (HCS) cost.
- Tracks statistics about various health states.

Intervention Analysis

Figure: Incidence/million in USB, FB, and total populations, given 0%, 50%, 75%, or 100% treatment of incoming LTBI.

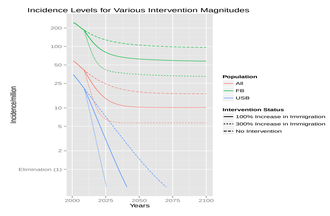

Figure: Incidence/million in USB, FB, and total populations, given 0%, 100%, or 300% LTBI treatment increase.

Economic Modeling

- Tracks treatment costs for various disease states
- Estimates implementation cost of intervention

Figure: Cumulative implementation costs, US HCS savings, and net US costs of LTBI arrival cure rates. Cost/case cured was \$600, \$800, and \$1000 for 50%, 75%, and 100% cured.

Base HCS Costs:

Active TB: \$14,014.90

LTBI: \$403.45

An Agent Based Implementation

Agent based models capture disease dynamics on the individual level, and reflect stochasticity and granularity lost in compartmental models. Agent based counterparts to the Hill model were implemented in Netlogo and c++.

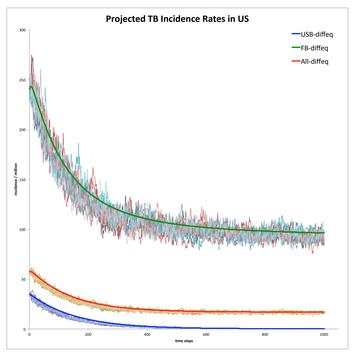

Figure: Incidence/million for R and NetLogo models (12 runs, $\Delta t = 0.1$, popConst $= 100$)

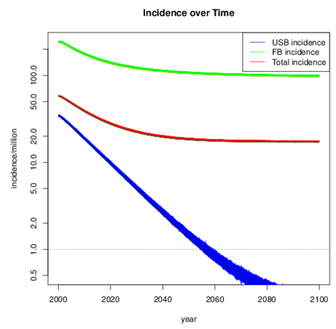

Figure: Incidence/million for R and C++ models (2100 runs, $\Delta t = 0.01$, popConst $= 1$)

Stochastic Models as a Measure of Variability

The stochastic model provides data on the variability of the results of the deterministic model.

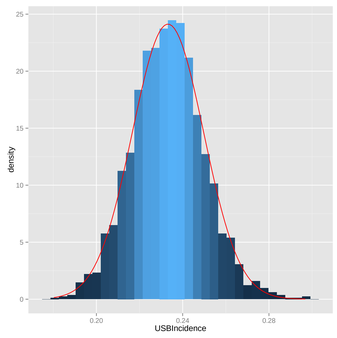

Figure: Distribution of USB Incidence (C++) with fitted Normal curve

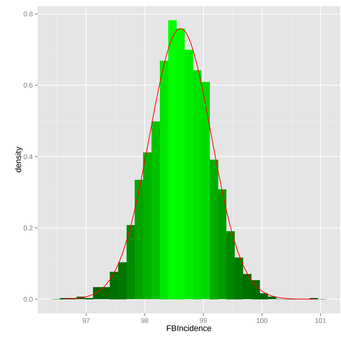

Figure: Distribution of FB Incidence (C++) with fitted Normal curve

Future Extensions

- Including contact structure
- Multi-drug resistant TB
- HIV

https://www.github.com/mmcdermott/disease-modeling