An agent-based model to simulate and predict HIV epidemic in Baltimore City, Maryland, USA

JOHNS HOPKINS MEDICINE

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Background

- Baltimore City has one of the highest rates of HIV incidence and prevalence in the United States. [Figure 1]

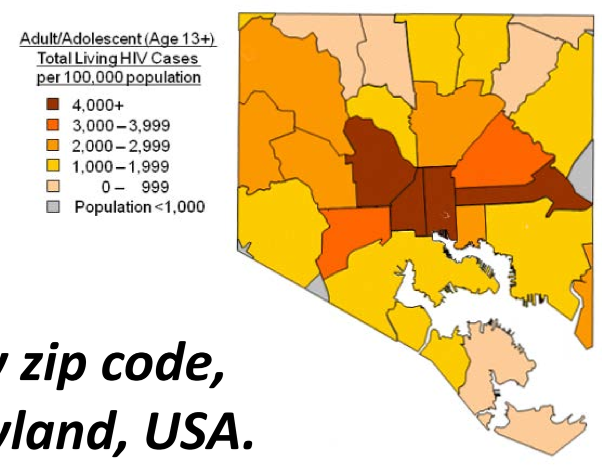

Fig 1. Prevalence of HIV by zip code, Baltimore City, Maryland, USA.

- An HIV testing program, implemented in several emergency departments (EDs), has accounted for 11% of newly diagnosed HIV cases from 2008-2013.

Objective

- We derive an agent-based model (ABM) for HIV transmission in Baltimore City, and use this to determine the significance of ED-based HIV testing on HIV transmission.

Results

CALIBRATION

- Each individual model was run 10 times for testing purposes [Figure 2].
- The parameter combinations which yielded the lowest error squared were:

Model	*Risk Ratio*	*Testing Rate (times/year)*	*Trans. Rate (prob. per person-week)*	*Error^2*
#1	12x	1	.0005	4.34E5
#2	11x	1	.0005	4.38E5
#3	11x	0.5	.0004	6.09E5

EFFECT OF TESTING RATES

- In Model #1, doubling testing rates resulted in 719 less new cases between 2007 and 2012 [Figure 3], and 665 less between 2012 and 2020. Accordingly, ED testing would have avoided 73 of those cases (11% overall).

FUTURE PREDICTIONS

- Assuming no change in current conditions, overall HIV incidence is forecast to decrease from 0.068% in 2013 to 0.032% in 2020 (80% CI: 0.025–0.065) [Figure 4].

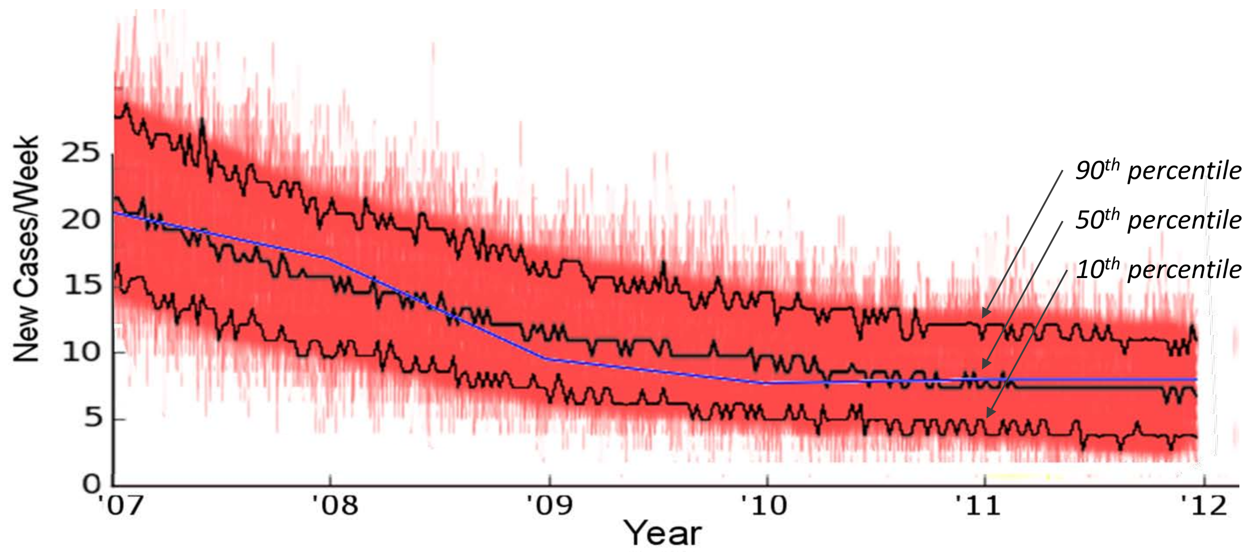

Fig 2. Simulated new cases/week of HIV vs. observed data (blue line), Model #1, 100 runs.

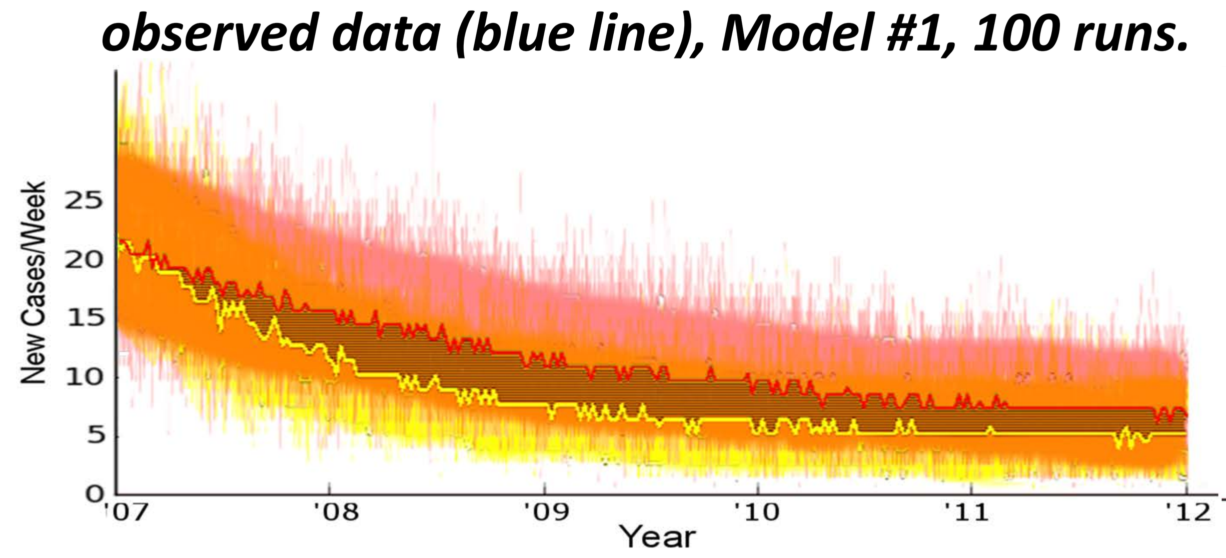

Fig 3. Consequences of doubling testing (yellow) vs. base case (red). The shaded area represents the number of HIV cases avoided. 100 runs.

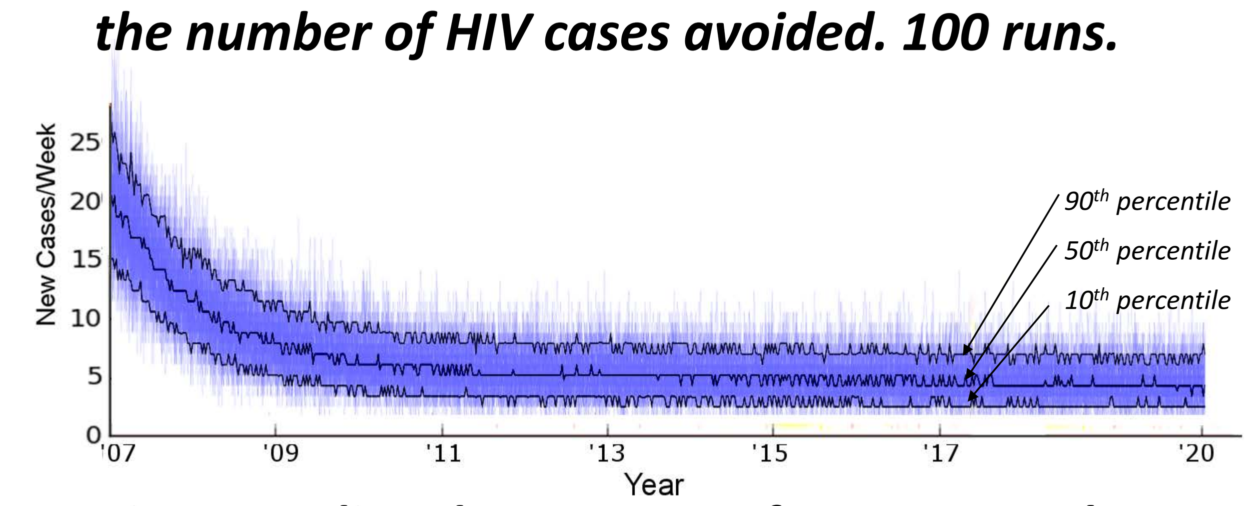

Fig 4. Predicted new cases of HIV per week through 2020. Model #1, 100 runs.

Methods

MODEL STRUCTURE

- Our computer-based simulation of the HIV epidemic in Baltimore City contains 523,113 agents, ages 13 and over, and begins on January 1, 2007.
- Agents are assigned to live in certain zip codes, and are assigned a serostatus to match the region's observed prevalence.
- During each timestep of one week, agents interact with other agents in their area, and seropositive agents possibly transmit HIV to seronegative agents.

KEY PARAMETERS

- Seropositive agents can be aware of their infection, or unaware, in which case they are more likely to transmit the disease by a variable factor denoted as *risk_ratio*.
- The overall probability of a transmission occurring per HIV-positive agent per timestep is described by a variable denoted as *overall_transmission*.
- HIV-positive agents unaware of their infection are able to be informed if they are tested in a particular timestep. The chance of them being tested per timestep is denoted by a variable *testing_rate*.

VARIABLES

- *Transmission Rate (transmission probability per person-week)*
  - *Range tested: $10^{-6} - 10^{-1}$*
- *Testing_rate (times/year)*
  - *Range tested: 0 – 2*
- *Risk_ratio (transmission risk multiplier for HIV+ & unaware)*
  - *Range tested: 2x – 20x*

CONSTANTS (from 2007 data)

- *Birth rate 1.4%/year*
- *Mortality rates:*
  - *HIV-, 1.22%/yr*
  - *HIV+, aware, 5%/yr*
  - *HIV+, unaware, 15%/yr*
- *Initial % of total HIV+ persons unware of positive serostatus: 34%*

CALIBRATION

- Models were evaluated by summing the squared difference of observed and expected values from 2007 to 2012.

Limitations

- Model did not factor the impact of antiretroviral treatment.
- We did not take into account migration of agents into and out of Baltimore.

Conclusions

- Agent-based models can capture elements of the complexity inherent in infectious disease transmission.
- Increasing the testing rate can have a large effect on the overall number of new cases.
- By increasing testing initiatives and awareness of HIV, we can very significantly decrease the number of new HIV cases per year.

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Contact

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