Expanding HAART to Control the Spread of HIV Among Injection Drug Users
A Mathematical Model

1 Background

Expanding antiretroviral therapy is considered a potential strategy for controlling the global HIV epidemic. Measurable drops in viral load and HIV incidence correlate with the introduction of HAART (Highly Active Antiretroviral Therapy). Mathematical models show that HAART can be an effective prevention strategy at the population level, but also raise concerns about unintended increases in HIV-related behaviour when HAART is widely available.

HIV epidemics can become extinct in the presence of social influences modifying risk behaviours. We previously showed, using a risk behaviour-driven, individual-based (cellular automaton) model of injection drug users (IDU), that HAART is very effective if social influence to discourage needle-sharing reaches a threshold level (Deblieghans et al., 2000). This effect is similar to herd immunity. We modelled the effect of an education-based biomedical intervention on the threshold. Therapy was implemented with or without a behavioural intervention to reduce needle-sharing among HAART recipients. We also tested the effect of initiating therapy early.

Our goal is to understand how epidemics are generated in differing risk environments and how interventions can impact this process. Epidemics were simulated over the entire range of social influence parameters and for 10 HAART coverage levels from 0 to 100%.

2 Model Structure and Simulations

The model is based on a Multi-Agent computational model and a cellular automaton (CA) simulating individual risk behaviour. Boxes are types of individuals: Stayers, HIV+ and HIV-. Arrows show social influences and transitions. Red arrows encourage, green arrows discourage needle-sharing. All except Stayers accumulate social influences from their neighbours. Once a threshold is reached, individuals may change class. When HIV+ and HIV- become undetectable, HAART is transmitted at a disease stage-specific probability. If needle-sharing among Stayers is stopped, HAART recipients reduce the region in the social influence plane where HIV is endemic. A needle-sharing epidemic is mapped similarly.

3 Scenarios and Parameters

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Figure 1. A model of a risk behaviour-driven HIV epidemic: Among Injection Drug Users.

Figure 2. Simulations of HAART Intervention Scenarios

100% HAART coverage eliminates epidemics even in the highest risk environments. Each phase diagram slice depicts where the social interaction plane HIV becomes extinct (green) or persistent (red). White dots show needle-sharing epidemics. Simulations were continued until equilibrium was reached, where HIV prevalence is constant in all scenarios (~ 40%). If those on HAART continue to share needles, HIV becomes endemic more easily (Scenario I). If those starting HAART stop sharing needles permanently, this effect is prevented completely (Scenario II). Initiating HAART earlier further magnifies this positive effect (Scenario III).

4 Results

Effect of HAART Coverage on Endemic HIV Region within Epidemic Phase-Diagram

5 Conclusions

Our modelling suggests that HAART has a positive impact on the HIV epidemic. Expanding HAART can potentially eliminate HIV, but in very high risk settings, 100% or close to 100% coverage may be required.

Our results support previous suggestions that HAART should be implemented in combination with behavioural interventions. In a very crowded, non-HAART environment, with no change in risk behaviour in HAART recipients, HAART leads to increased HIV prevalence. This scenario is likely to be unrealistic for many drug treatment programs, where support is provided to reduce needle-sharing. Nonetheless, the results underline the importance of targeting risk behaviour in HAART recipients.

Measuring incidence may provide more complete information on the impact of HAART. We found previously that in the endemic regions prevalence was constant at close to 40%. This was confirmed for all endemic regions in this study. Since HIV transmission and death rates are reduced, while the expectation increases substantially for HAART recipients, we may find that incidence drops when HAART is implemented. This means that incidence should be used in assessment of the impact of HAART on the HIV epidemic.

Earlier initiation of HAART appear to have a beneficial effect on the epidemic.

6 Next Steps

Measuring incidence - We will modify the model so that new infections are tracked to provide an improved measure of any intervention to control the HIV epidemic.

Behavioural interventions for those not on HAART - We did not include behavioural interventions for anyone not starting HAART in the current model. Variations in adherence will be considered in future versions.

Tuning of HAART - To fully understand the impact of HAART, we will conduct more complete sensitivity analyses for various settings.

Social influence scale - Our social influence scale is an abstract conceptualisation of influences that are likely to drive needle-sharing among IDU. We intend to work with social scientists to find or develop measurable social influence scales that can be used to inform the model.

For more information please contact Natasha Richardson at

N Richardson, AR Rutherford, B Ramadonovic, B Marshall, A Kaida, P Bastani, A van der Waal, JSG Montaner, VD Lima, K Fernandes, HS Hogg, P Bonnem, K Veazey

The IMPACT-HIV Group

A Collaboration of the
BC Centre for Excellence In HIV/AIDS, Vancouver, Canada and the
Complex Systems Modelling Group, Simon Fraser University, Burnaby, Canada

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