Modelling of vaccination and treatment campaigns
(work in collaboration with Drs. Marie-Claude Boily and Simon de Montigny)

In the context of the HIV epidemic, we have developed mathematical models to evaluate the impact of HIV vaccination campaign and HIV treatment programmes in the era of universal access to ART (see brief description below). This work can be adapted to the SARS-Cov-2 pandemic and the Canadian context. We are currently developing transmission dynamic models to understand the impact of future biomedical interventions on the COVID-19 epidemic.

HIV Vaccination campaign[1]
Promising multi-dose HIV vaccine regimens are being tested in trials in South Africa. We estimated the potential epidemiological and economic impact of HIV vaccine campaigns compared to continuous vaccination, assuming that vaccine efficacy is transient and dependent on immune response. We used a dynamic economic mathematical model of HIV transmission calibrated to 2012 epidemiological data to simulate vaccination with anticipated antiretroviral treatment scale-up in South Africa. We estimate that biennial vaccination with a 70% efficacious vaccine reaching 20% of the sexually active population could prevent 480,000-650,000 HIV infections (13.8-15.3% of all infections) over 10 years. Assuming a launch price of $15 per dose, vaccination was found to be cost-effective, with an incremental cost-effectiveness ratio of $13,746 per quality-adjusted life-year as compared to no vaccination. Increasing vaccination coverage to 50% will prevent more infections but is less likely to achieve cost-effectiveness. Campaign vaccination is consistently more effective and costs less than continuous vaccination across scenarios. Results suggest that a partially effective HIV vaccine will have substantial impact on the HIV epidemic in South Africa and offer good value if priced less than $105 for a five-dose series. Vaccination campaigns every two years may offer greater value for money than continuous vaccination reaching the same coverage level.

HIV treatment programmes in the era of universal access to ART[2]
The epidemiological tipping point ratio (TPR) has been suggested as a useful indicator to monitor the scale-up of antiretroviral treatment (ART) programmes and determine when scale-up is sufficient to control the epidemic. TPR has been defined as the ratio of yearly number of new HIV infections to the yearly number of new ART initiations or to the yearly net increase in the number of people on ART. It has been used to rank the progress of treatment programmes across countries, with the objective of reaching a TPR value under 1. Our study aims to assess if TPR alone can be used as an indicator of ART success across settings by comparing the expected changes in HIV incidence and ART coverage when TPR is maintained constant over time. In particular, we focus on the effect of ART initiation timing (emphasis on ART being initiated early or late during HIV progression) on the interpretation of the TPR.

We used a dynamic model of HIV transmission in South Africa representing ART rollout leading to universal treatment in 2017. The model is calibrated to HIV incidence, HIV

prevalence and ART coverage in 2012 in South Africa, and 1000 simulations are selected for the base-case scenario. To measure the effect of TPR, we simulate TPR-preserving interventions, maintaining TPR (yearly number of new ART initiations denominator) at the value observed in 2019 (between 0.65 and 1.25) for 15 years. We compare ART coverage and HIV incidence across TPR values and across strategies in which ART access is prioritized differently. In a secondary analysis, we illustrate the sensitivity of new ART initiations to ART retention, and we compare both definitions of the TPR.

Our analysis shows that HIV incidence reduction is weakly correlated to TPR: the same reduction in HIV incidence (15%) can be achieved by implementing the same strategy with a wide range of TPR maintained (0.65-1.12). Assuming high retention in ART, TPR-preserving strategies prioritizing early ART initiation yield greater reduction in HIV incidence than strategies where most individuals initiate ART late. High ART coverage is associated with low HIV incidence and it can be reached with a TPR below or equal to one with strategies favoring early ART initiation. Low ART retention over time results in higher HIV incidence even if TPR is maintained low. If ART retention is low, strategies prioritizing late ART initiation are associated with lower HIV incidence than strategies where ART is initiated early. Maintaining a fixed TPR value based on the net increase in people on ART gives higher HIV incidence reduction and requires fast ART scale-up.

Our analysis suggests that the TPR is not an adequate indicator of ART programme impact, without information on ART coverage and retention. Achieving early initiation and adherence to treatment to improve ART coverage might be as important as attaining a specific TPR target. Comparisons of TPR in different settings should account for differences in epidemic conditions.

References:

[1] **de Montigny S**, Adamson BJS, **Mâsse BR**, Garrison LP Jr, Kublin JG, Gilbert PB, Dimitrov DT. Projected effectiveness and added value of HIV vaccination campaigns in South Africa: A modeling study. Sci Rep. 2018 Apr 17;8(1):6066. doi: 10.1038/s41598-018-24268-4. PubMed PMID: 29666455; PubMed Central PMCID: PMC5904131.

[2] **de Montigny S, Boily MC, Mâsse BR**, Mitchell KM, Dimitrov DT. Assessing the utility of the tipping point ratio to monitor HIV treatment programmes in the era of universal access to ART. Infect Dis Model. 2018 Mar 14;3:85-96. doi: 10.1016/j.idm.2018.03.005. eCollection 2018. PubMed PMID: 30839944; PubMed Central PMCID: PMC6326263.