Sources of HIV-1 transmission in the test and treat era: A mathematical modelling study

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BACKGROUND

The scale-up of antiretroviral therapy (ART) and VMMC in sub-Saharan Africa (SSA) over the last decade has contributed to substantial declines in HIV risk and mortality, yet incidence remains high (> 1%) across regions of eastern and southern Africa. Identifying the sources and timing of persistent transmission in the era of universal test and treat (UTT) will be necessary to prioritize further interventions to drive incidence towards epidemic control (incidence < 1/1000 person-years).

METHODS

We used a stochastic, agent-based epidemic model, calibrated to the HIV epidemic in the Kingdom of Eswatini[1] to estimate the composition of HIV transmissions from the perspective of the transmitting individual by demographic group (age and sex), stage of infection [acute (<3 months from infection, latent (3 months-ART initiation or AIDS), AIDS], and time from HIV acquisition. We compared transmission patterns in 2010, prior to UTT, and in 2020, after UTT. We also projected transmission over the next thirty years under scenarios with ART coverage maintained at 90-90-90 levels (pessimistic) and with ART at 100% initiation within 6 months of infection (optimistic).

RESULTS

1. ART scale-up has had the largest effect in reducing transmission from PLHIV in the latent stage of infection (Figure 1).
   - Prior to UTT, 70% of adult HIV incidence (2% per person-year) arose from PLHIV with latent HIV infection
   - After UTT, this declined to 40% of incidence (0.5%/PY)
2. Transmissions from acutely infected PLHIV (<3 mos. from acquisition) declined in absolute terms, but increased as a proportion of total transmissions after UTT.
   - Prior to UTT, 10% of adult HIV incidence (0.5%/PY) was due to acute HIV infection
   - After UTT, 15% of adult HIV incidence (0.25%/PY) was due to acute HIV infection
3. Both the absolute and relative contribution to transmission from individuals on ART increased after UTT
4. In the UTT era, most infections (50-60%) in young men and women (<25) were from individuals infected for < 1 year (Figure 2)

As ART coverage scales up, the contribution to incidence from individuals in the acute/early stage and individuals who have initiated ART will increase.

Most new infections in young adults (50-60%) will be from individuals infected for < 1 year.

Figure 1. Sources of HIV transmission by infection stage. **Left panel**: contribution to overall incidence. **Right panel:** percent of all transmissions

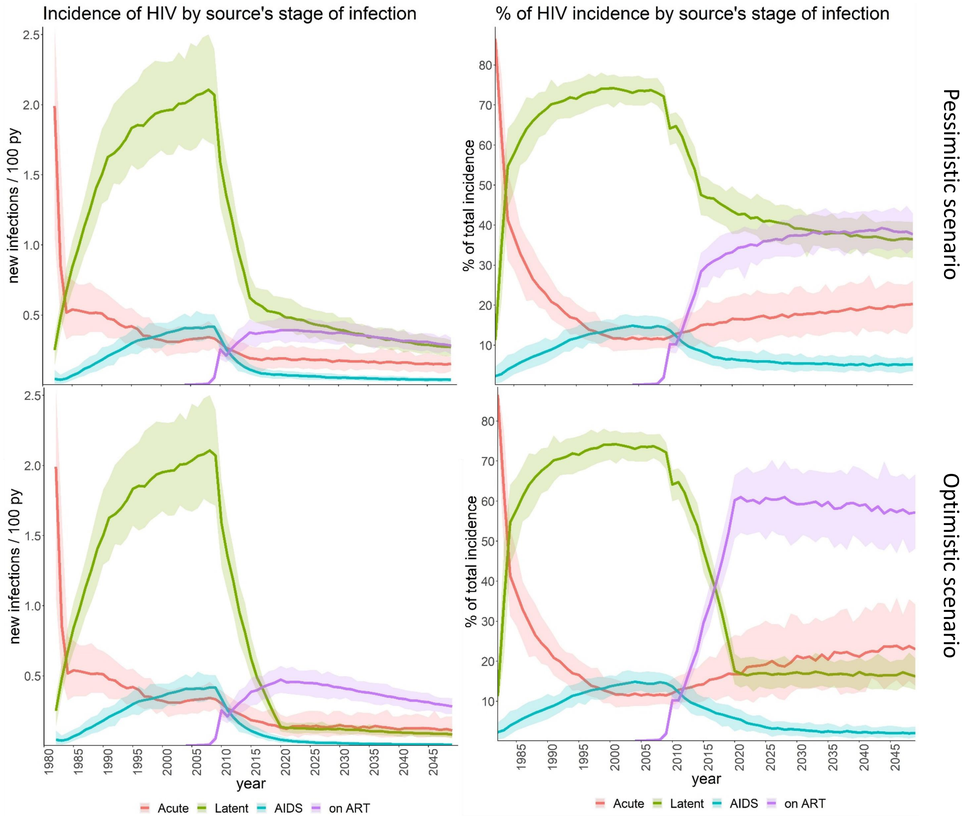
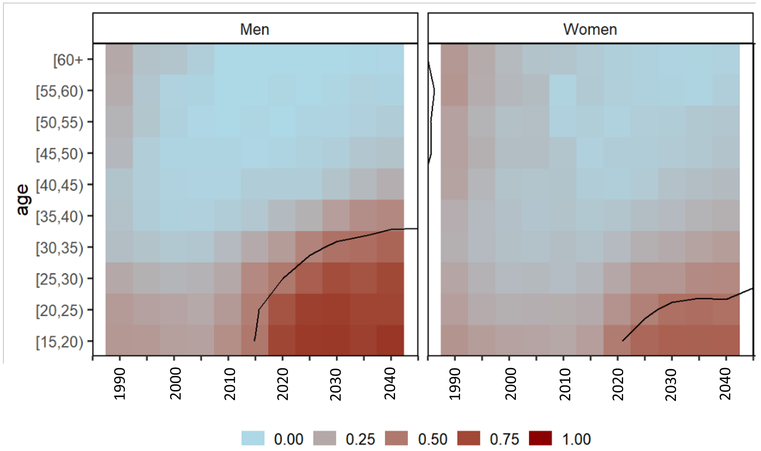


Figure 2. Proportion of transmissions from PLHIV infected for < 1 year by age of the recipient.



CONCLUSIONS

Despite dramatic reductions in HIV incidence and mortality in sub-Saharan Africa over the last ten years, incidence remains an order of magnitude above epidemic control thresholds, even in countries that have met or exceeded global treatment targets. We found that incidence above 1% can be sustained in the era of universal test and treat. This residual incidence is due to transmissions from three major sources:

- PLHIV with acute HIV infection (20% of transmission)
- PLHIV currently on ART (40% of transmission),
- PLHIV not currently on ART (40% of transmissions).

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References:

1. Akullian A, Morrison M, Garnett G, Mnisi Z, Lukhele N, Bridenbecker D, and Bershteyn A. “The effect of 90-90-90 on HIV-1 incidence and mortality in eSwatini: a mathematical modelling study.” Lancet HIV 7(5):e348–58, 2020.

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